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ABSTRACT

This publication is the first product of a project to update and reorder the Science Syllabus for Middle and Junior High Schools in the state of New York. The performance objectives and criteria are provided in a general outline in the first section, which conforms to the content subdivisions in the three "processes" sections: (1) Living Things, (2) Survival of Living Things, and (3) Ecology. These three sections are of the same format "Concepts and Understandings" and their corresponding "Questions and Activities." A list of processes is also included as is a large appendix of learning activities. The publication is designed so that the understandings, questions, and learning activities are enhanced by the inclusion and referencing of program objectives, performance criteria, and process skills. Environmental considerations are infused throughout and the importance of consumer and career implications in a science program is specifically acknowledged. This syllabus could be adapted to a variety of science education situations. (MR)

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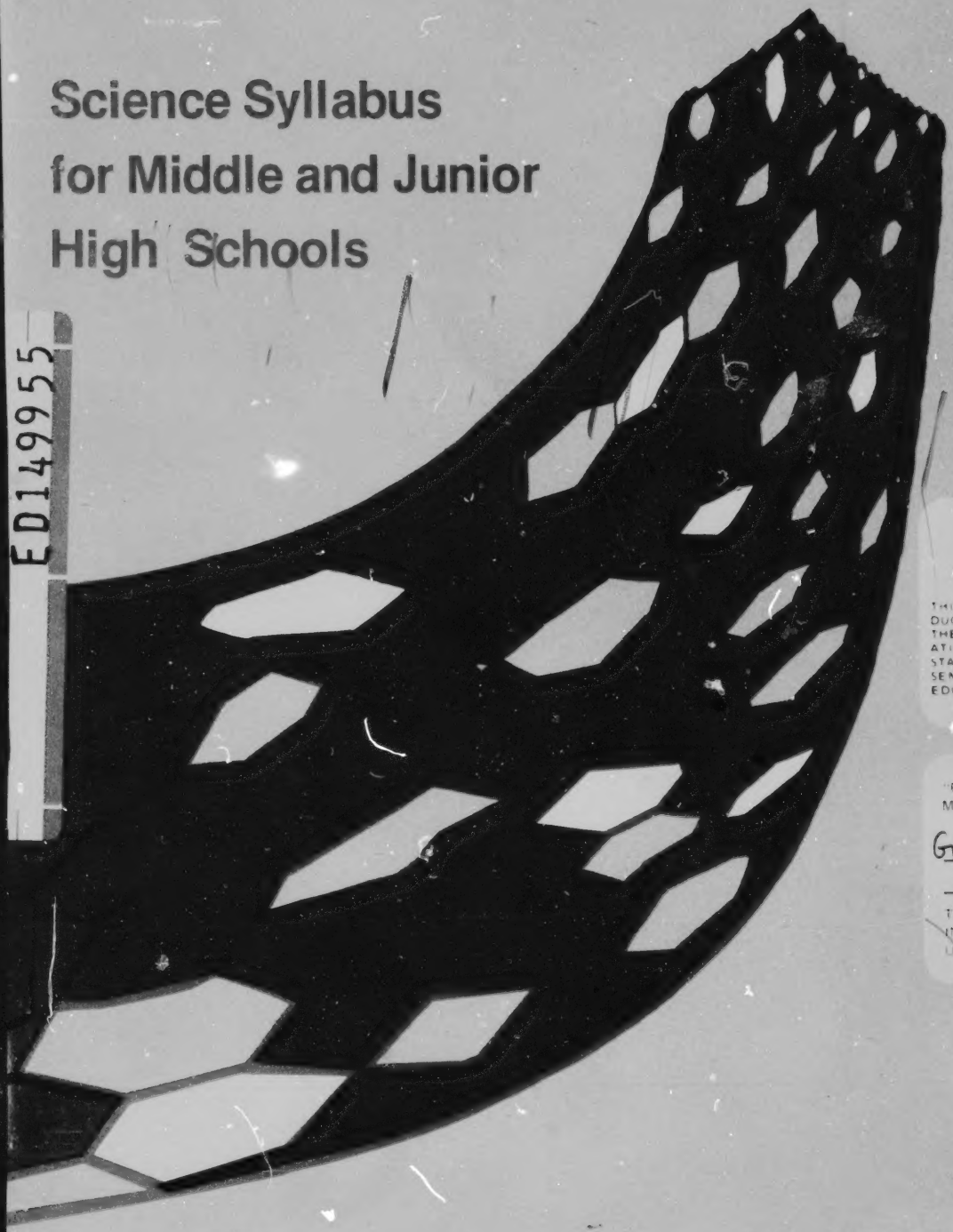
Science Syllabus for Middle and Junior High Schools



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LIVING SYSTEMS

ORGANISMS

block A

2

SE 022 616

SCIENCE SYLLABUS

FOR

MIDDLE AND JUNIOR HIGH SCHOOLS

BLOCK A

LIVING SYSTEMS: ORGANISMS

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Bureau of General Education Curriculum Development
Albany, New York 12234

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Director, Division of General Education
Ted T. Grenda

Chief, Bureau of Science Education
Edward T. Lalor

FOREWORD

This publication is the first product of the project to significantly update and reorder the Science Syllabus for Middle and Junior High Schools. The project will result in a group of instructional blocks encompassing the content and skills in the biological, physical, and earth sciences appropriate for the grade levels indicated above. *Block A — Living Systems: Organisms* is the first of three publications that will deal with the biological sciences, and these will be followed by additional blocks in each of the areas of the physical sciences and the earth sciences.

The understandings, questions, and learning activities in the publication have been enhanced by the inclusion and referencing of program objectives, performance criteria, and process skills which serve to focus student achievement. Thus, environmental considerations are infused throughout the content material and the importance of consumer and career implications in a science program is specifically acknowledged.

The objectives and performance criteria are provided in a general outline on pages 1 through 3 which conforms to the content subdivisions in the publication; the process skills are keyed to the learning activities; and the learning activities are keyed to the understandings and the questions.

The development of this syllabus was coordinated within the Bureau of General Education Curriculum Development by Barry W. Jamason, associate. Gerald Cerne, South Colonie School District, revised portions of the content material while reviewing the entire manuscript. Rose R. Dill, Schodack Central School District, added environmental education understandings to the publication. Edward T. Lalor, Chief, Bureau of Science Education, and William A. Calhoun, associate in science education, reviewed all materials and made valuable suggestions for content improvement and accuracy. The cover design was created by Oscar A. Kaufman, Oaktree Films.

Herbert Bothamley, *Chief*
Bureau of General Education
Curriculum Development

Gordon E. Van Hooft, *Director*
Division for Curriculum Services

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PROGRAM OBJECTIVES AND PERFORMANCE CRITERIA

The program objectives and performance criteria below are provided as an aid in ordering the direction and synthesizing the outcomes of the instruction related to this block. The objectives and outcomes (performance) described below for this program permit latitude in the selection of content. It is implied that student knowledge, understanding, and skills accrued as a result of content selection and instruction will be demonstrable in the manner, and to the minimum extent, described.

Program Objectives	*Performance Criteria*
I. LIVING THINGS	
The student will be able to describe the organization of living things and the way these things interact with each other within their environment.	Given an example of a living thing, the student will indicate the common traits that distinguish living from nonliving things.
	Given an appropriate organism, the student will describe the climatic and/or physical conditions of the environment it requires for life.
	Given a list of plants or animals, the student will be able to classify them into appropriate groups.
The student will be able to describe and predict the effects of environmental changes on the interactions of living things.	Given a situation which describes a change in climatic and/or physical conditions, the student will predict its effect on organisms exposed to this change.
II. SURVIVAL OF LIVING THINGS	
The student will be able to describe the conditions of survival and the importance of interdependence through descriptions of the food-gathering and reproductive activities of living things.	Given an organism, the student will describe how the organism obtains and uses food and will classify the nutrients in the food.
	Given an appropriate living thing (organism), the student will describe the type(s) of process by which the organism reproduces and classify the process as sexual or asexual.
	Given an appropriate organism, the student will describe its life cycle.

Program Objectives	*Performance Criteria*
The student will be able to identify and categorize human activity which affects natural environments or systems while describing these effects.	Given a case study involving a type of pollution and the life cycle of an organism, the student will indicate how this pollution affects the capacity of this organism to survive.

III. ECOLOGY

The student will be able to describe the types of natural communities and to illustrate the concept of balance in these communities.	Given a set of physical conditions or dominant vegetation, the student will classify the community or biome described. Given a list of the organisms and conditions of a natural community, the student will describe the energy and matter flow of the three major organisms comprising the food chains involved.
The student will be able to assess the importance of natural systems and environments in terms of the resources they represent.	Given a natural resource, the student will describe the characteristics, use, and conservation principles related to this resource.
The student will be able to state and substantiate environmental imperatives in view of man's logical role as steward of the environment.	Given an individual or societal case study involving use of resources, the student will cite the choices made and the values implied in the choices made.

Throughout this program the instructor should be cognizant of the importance of including several related objectives and performance criteria which represent the practical infusion of career and consumer considerations as they relate to science education:

The student will be able to describe the career opportunities and the knowledge, skills, and attitudes helpful in those careers and occupations allied with the subject matter.	Given a career or occupational classification related to the subject material, the student will describe activities carried out in this work. Given an occupational role related to the subject material, the student will describe the training and aptitudes required to perform the role.

Program Objectives	*Performance Criteria*
	Given an opportunity, the student will describe currently practiced work habits, skills and knowledge that relate to careers implied in the subject material.
The student will be able to describe the economic implications for society of understanding the concepts of interdependence, balance, survival, and conservation as they pertain to natural and human communities.	Given a pattern of relationships, such as a food chain, the student will construct a case study which illustrates the context of human interaction within and with such a chain.
	Given a natural resource, the student will characterize the resource in terms of economic importance, availability, renewability, and significance to human and other biotic activity.

PROCESSES

One of the major objectives in all science courses is the development of competence in processes used in science. The learning activities in this publication will assist students in attaining this objective. Each activity is keyed to one or more of the processes listed below. For example, activity (A-1) involves processes [1], [5], and [14]. In general, the processes are listed in order of predominance within the activity and appear to the right of the activity's title.

[1] Observing objects and phenomena

[2] Describing observations

[3] Selecting suitable measuring instruments

[4] Developing skills in using laboratory equipment

[5] Measuring objects and phenomena

[6] Performing laboratory techniques

[7] Estimating measurements within limits of accuracy

[8] Recognizing a problem

[9] Formulating a working hypothesis

[10] Designing appropriate tests of a hypothesis

[11] Designing suitable procedures for experimental tests

[12] Processing experimental data

[13] Organizing data to show a functional relationship

[14] Interpreting observations and data

[15] Interpolating and extrapolating

[16] Evaluating a hypothesis in the light of data obtained

[17] Formulating generalizations based on relationships

[18] Recognizing the need for a theoretical model

[19] Formulating a theoretical model to accommodate knowledge

[20] Designing relationships satisfied by a model

[21] Deducing a hypothesis from a theoretical model

[22] Interpreting and evaluating tests of a model

[23] Producing a revised, refined, or extended model

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
I Living Things	
A Characteristics	
All living things contain cells or highly organized protoplasm.	*What are some characteristics common to all living things?* (A-1)
All living things have certain traits in common that make them different from nonliving things.	
Living things are in constant contact with their environment and they continually exchange materials with the environment.	
1 movement	
Living things are capable of independent movement, either within the cell or the body as a whole.[1]	*What is the difference in the way movement is produced in plants and the way it is produced in animals?* (A-2, A-3)
All protoplasm has some power of contraction that produces movement, but this ability is most highly developed in muscle cells.	
Most plants and some animals, such as sponges, corals, and barnacles do not move around from place to place. There is nevertheless, much movement taking place within their bodies.	
Movement in plants is slower than that in animals, and usually results from differential growth.[2]	
Leaves of plants turn toward light because the cells in the side of the stem away from light grow faster than those on the lighted side. Thus, the dark side of the stem is slightly longer than the other side, bending the stem in the direction of the light.	*What is phototropism?*

[1]An automobile moves because of the burning of fuel. A rabbit moves because of the slow burning of food or fuel in its cells. However, with the rabbit the movement is independently controlled, while an outside control is necessary in the case of the automobile.

[2]While most movement in plants is usually due to differential growth, movement is much more rapid in sensitive plants (mimosa, and the Venus Fly Trap), and results from rapid changes in the water content of certain cells (Nastic Movement).

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 need for food	
All living things require food to provide energy and the raw materials for growth and repair.	
Plants and animals use similar food substances but they are obtained in different ways.	
Photosynthetic activity by green plants changes sunlight into metabolic energy by manufacturing foods.	*What evidence is there that plants make their own food?*
Food substances that cannot be produced by a living thing must be supplied to it from the environment.	
Carbohydrates, fats, and proteins can be produced by plants from simple inorganic substances; animals are dependent on plants for these substances either directly or indirectly.	*Why are animals dependent upon plants for food?* (A-4)
3 need for energy	
Green plants use light energy to make food (photosynthesis).	
All living things including plants must be able to release this energy from their food (respiration) in order to carry on their life activities.	
Most living things use oxygen during respiration.	*Why do most living things need oxygen?*[3] (A-5, A-6)
Oxygen combines chemically with food to release energy.	
Oxygen is obtained by most organisms either from the atmosphere or from solution in water.	

[3]It is difficult to show that green plants require oxygen when exposed to light. Because of the great volume of oxygen produced during photosynthesis, there is an excess over and above the plant's own needs which is excreted.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Some protists (yeasts) do not require oxygen for respiration.	
Energy is initially supplied to an ecosystem by the activities of green plants.	
4 need for water	
Water is essential to life and is provided by the physical environment.	
Water is a reusable and transient resource, but the usable quality may be reduced by impaired quality.	
The bodies of living things are from 65 percent to 95 percent water.	
Water is needed as a solvent in living cells.	*What is the major purpose for which living things need water?*
Some animals obtain needed water from their food.	
Green plants need water for photosynthesis.	*Why do green plants need water?* (A-7)
5 need for proper temperature	
Active life of cells is limited to a range of temperature from the freezing point of water to about 42.8°C (109°F).	*What is the relationship between cell activity and temperature?*
Some plant species survive the winter as dormant seeds.	*Give some examples of plants that become dormant?*
Some plants lose their leaves and become dormant during the winter.	
The body temperature and activity of coldblooded animals varies with the surroundings.	*Explain how it is possible to tell the air temperature by counting the number of chirps a cricket makes per minute?* (A-8)

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Warmblooded animals have a constant body temperature and can remain active at low outside temperatures.[4]	*How does frostbite occur?*
Some living things remain dormant or hibernate during cold periods of the year. Others migrate to warmer climates.	*What changes in body activities take place during hibernation?*
6 irritability	
All living things respond to stimuli in their environment.	*Why is it important for living things to be able to respond to changes in their environment?* (A-9, A-10)
Responses made by living things are usually expressed by movement, secretion, or growth.	
7 reproduction	
Reproduction provides for the continuance of life by providing new individuals.	
All living things die, but life continues.	
8 excretion	
All living things eliminate waste by excretion.	
B Adaptations	
Survival of an organism depends upon its ability to adjust to its environment. Each kind of organism represents a collection of adaptations which fit it for survival under a given set of conditions.	*What are some ways in which organisms may adapt to changes in their environments?*

[4]The temperature limitations of life apply to individual cells. Warmblooded animals are therefore able to function at low outside temperatures. The individual cells of a man shoveling snow at 23.3°C (-10°F) are still in an environment that is very close to 36.6°C (98°F).

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Living things will be found in the particular environment that provides the conditions they require for life.	*What kinds of habitats are found around the school grounds?*[5] (A-11, A-12)
The place where a plant or animals lives is called its habitat.	
Living things are adapted to their environment.	
1 climatic	
a arctic conditions	
Plants in the far north have a short growing season.	
Many adaptations, such as protective coloration, body fat, thick covering (fur or plumage), and migratory or hibernant habits, help animals survive the harsh environment of the tundra.	*In what ways are the arctic hare and the polar bear adapted to their environment?*[6] (A-13)
	What effect could extensive human activity (oildrilling, mining) have upon the arctic region?[7]
b desert conditions	
Desert plants adapt to the environment as drought-evaders (seed dormancy) or drought-resisters (water-storing stems, deep, water-seeking roots, and waxy or spiny leaves which inhibit water loss through transpiration.)[8]	*In what ways are cactus plants adapted to life in the desert?*
Desert animals adapt to the harsh environment by:	
becoming dormant during unfavorable conditions; being light-colored; being nocturnal; and having body temperatures which respond to the environment; or by possessing thick coats.	

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[5]Refer to the Department publication Environmental Education Curriculum Infusion Units for grades 7-12, pp. 108-109 (Wildlife Habitats).

[6]Animals of the arctic are often white in color to blend in with the surrounding ice and snow.

[7]Conditions above the timberline (tundra) are characterized by very low temperatures, low precipitation, short growing seasons, and a scarcity of liquid water during much of the year. Bogs and ponds form from melting ice and snow. Vegetation is low and consists of lichens, mosses, and some flowering plants. Animals are mainly migratory or dormant during unfavorable conditions.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 physical	
a life in water	
Most aquatic organisms need dissolved oxygen to live. The need for oxygen is called the biological oxygen demand (BOD). The demand varies with the particular organism. Decaying materials, sewage, and chemicals decrease the amount of oxygen in water.	*How does polluted water affect plant and animal life in water?*
Many water animals have gills to extract the oxygen dissolved in water and fins with which to swim.[9]	*In what ways is a goldfish adapted to life in water?* (A-14)
Some air-breathing animals, such as frogs, beavers, and ducks are adapted to swimming by having webs of skin between their toes.	
Water plants are supported by the water and thus have much weaker stems than do land plants.	*Why do water plants usually not have strong stems?* (A-15)
b life in soil	
Many animals are adapted to life in the soil.	*In what ways are animals adapted to living in soil?*[10] (A-16)
Worms and insects make up the bulk of the animal life found in soil.	
Plants are adapted to anchor themselves in the soil and absorb water.	*How does the soil serve as a habitat for plants?*[11] (A-17, A-18)
c life in air	
Birds are adapted to life in the air. They have hollow, air-filled bones that make them light and feathers to give their wings a large surface area.	*Why can mosquitoes, canaries, and bats fly while humans cannot?*[12] (A-19)
	Do "flying squirrels" fly?[13]

[8]Deserts are land areas where evaporation exceeds precipitation. Water is scarce. Humidity is low and day-night temperature extremes are great.

[9]Whales, dolphins, and porpoises are air-breathing mammals that have flippers and tail fins for swimming. They have horizontal tail fins instead of the vertical ones possessed by fish.

[10]Soil animals are small, have little coloration, and have poor eyesight.

[11]High organic content soils provide food materials (water, minerals) for plants.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Insects also have light bodies with air tubes and many are equipped with wings for flight.	
Land plants are equipped with supporting tissue to hold them upright and with methods of preventing water loss. Both of these are lacking in water plants.	*How is a geranium adapted to life in air, while seaweed is not?*
C Classification	
1 need	
There are well over a million kinds of protists, plants, and animals.	
The great number and variety of organisms makes a system of classification necessary.	*Why is it necessary to classify protists, plants, and animals?* (A-20)
2 method	
Classification systems are artificial constructions designed by man in an effort to organize the tremendous variety of living things by grouping together organisms having similar characteristics.	
The modern classification system is based upon evolutionary relationships.	*How is structure used as a basis for classification?* (A-21)
3 principles	
All organisms are divided into three great groups or kingdoms: protist, plant, and animal. Protists include both plant-like and animal-like primative organisms (unicellular organisms), and plant-like organisms whose bodies show little distinction among tissues (multicellular algae and fungi).	*What is the general scheme by which living things are classified?* (A-22) *What are some of the differences among protists, plants, and animals?*

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[12]Bats are mammals that are capable of flight because of great flaps of skin that stretch from front to hind leg on each side.

[13]"Flying" squirrels do not actually fly. They are capable of gliding from higher to lower levels by means of skin flaps attached to both front and hind legs.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Plants are multicellular organisms whose cells have a rigid wall of cellulose surrounding the cell membrane.	
Animals are multicellular organisms whose cells lack a cellulose cell wall.	
Each kingdom is divided into a number of major groups, each of which is called a phylum. All the members of a phylum have certain characteristics in common.	
Each phylum is divided and subdivided into smaller and smaller groups.	
The smallest grouping of similar organisms is the genus. The individual kinds of similar organisms grouped into a genus are species.	
4 scientific names	
Each kind of organism has a scientific name which is the same the world over. The scientific name is the genus and species name of the organism.	*Why are scientific names important?*
5 major groups of protists	
There are five major groups of protists.[14]	
a bacteria	
Bacteria are among the smallest protists. Most cannot make their own food. Bacteria lack an organized nucleus but have a cell wall.	
b fungi	
Fungi have a cell wall and a nucleus, but lack chloroplyll. They include the molds, mushrooms, and yeasts.	

[14]Viruses are unique biological systems, neither living nor nonliving, but viewed by some biologists as a bridge between the two. Viruses lack cells and cannot be seen with a light microscope.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
c protozoa	
Protozoa are mainly single-celled, solitary organisms although some exist as colonies. Protozoa lack a cellulose cell wall found in other protists.[15]	*What are the names of some common protozoa?* (A-23) *In what ways are all protozoa alike?*
d slime mold	
Slime molds are so named because at one stage they are a slimy mass. Their cells at one stage are able to move like an ameba. At another stage, the slime mold develops mold-like spore cases.	
e algae	
Algae possess chlorophyll and a cell wall. Many algae are unicellular. The multicellular algae are considered protists since their bodies show little distinction among tissues (lack leaves, stems, and roots).	*How is an alga different from a fungus?* (A-24)
6 major groups of plants	
There are two major groups of plants.	
a bryophytes	
The bryophytes (mosses) are plants with simple leaves, but since they lack vascular tissues, their size is limited.	*Why are all mosses small plants, and why are mosses always found growing in moist places?*[16] (A-25)
b tracheophytes	
The tracheophytes have a vascular (conducting) system. They have roots, stems, and leaves. The three major types are: ferns, conifers, and flowering plants.	

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[15]Some protozoa have chlorophyll-like algae, but lack the cellulose cell wall of other protists.

[16]Mosses have structures that function as roots, anchoring the plant and absorbing water. However, these structures do not have the internal structure of true roots. Because they lack conducting tissue, mosses are limited in size and confined to moist habitats.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(1) ferns	
Ferns do not produce seeds. They reproduce by means of microscopic spores produced on the underside of the leaves or on special stems.	*Why can ferns grow larger than mosses?* (A-26)
(2) conifers	
Conifers produce their seeds in cones.	*Why are the seed-producing plants considered to be the most highly developed plants?*
(3) flowering plants	
Flowering plants produce their seeds in fruit that develops from the flowers.	
7 major groups of animals	
The animal kingdom is divided into many different phyla.[17]	
a animals with outside skeletons	
The largest group of invertebrates is the phylum Arthropoda. Arthropods have skeletons outside their bodies (exoskeletons); their bodies are jointed, and they have legs. There are five main divisions to the Arthropoda phylum.	
(1) centipedes	
Centipedes have one pair of legs per body section.	
(2) millipedes	
Millipedes have two pairs of legs per body section.	

[17]Sometimes it is convenient to group animals into one of two main categories: invertebrate or vertebrate. Animals without backbones are called invertebrates. Vertebrates have an internal skeleton with a jointed backbone.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(3) crustacea	
Crayfish, lobsters, shrimp, and crabs are included in another division of the Arthropods. They all have five pairs of legs.	*What important food animals are included in the group Crustacea?*
(4) spiders	
Spiders have two body sections and four pairs of legs. Ticks and mites are included in this same division.	*How are spiders different from insects?* (A-27)
(5) insects	
Insects have three body sections and three pairs of legs.	*In what way are insects important in your life?* (A-28)[18]
b animals with backbones	
All vertebrates have internal skeletons and jointed backbones. There are five main groups of vertebrates. (phylum Chordata)	
(1) fish	
Fish are coldblooded, extract oxygen from the water by means of gills, and are covered with scales.	*Why is the skin of some fish, like the catfish, smooth?*[19]
(2) amphibians	
Amphibia are coldblooded and have gills when young and lungs as adults. They are covered by a smooth, often slimy skin. Frogs, toads, and salamanders are included in the class Amphibia.	*Why should toads in a garden be protected?*[20] (A-29)

[18]Many insects are predators and may be used to control unwanted insects. Braconids are parasitic wasps. Ichneumon flies are insect larva predators. Trachina flies are predators of gypsy moths. Praying mantids and spring typhia control Japanese beetles.

[19]In some fish, such as catfish and trout, the scales are microscopic and buried in the skin.

[20]Toads are predators of garden pests (insects, snails, slugs). Predatory animals help keep a balance in nature.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(3) reptiles	
Reptiles are also coldblooded, but have lungs throughout their life cycles. They are covered with scales. Snakes, turtles, alligators, and crocodiles are the major divisions of the reptile group.	*What are the distinguishing characteristics of reptiles?* (A-30)
(4) birds	
Birds are warmblooded, breathe by means of lungs throughout their lives, and are covered with feathers.	*What birds cannot fly? Why?*
	Why is the ability to fly not one of the distinguishing characteristics of birds? (A-31, A-32)
(5) mammals	
Mammals are warmblooded, breathe by means of lungs throughout their lives, and have hair growing over their bodies. They feed their young with milk produced by mammary glands.	*What two groups of vertebrates are warmblooded?* (A-33, A-34)
II Survival of Living Things	
Living things are interdependent with one another and with their environment. Survival depends upon the ability of an organism to adjust to its environment.	
A Obtaining food	
Plants are called producers. The glucose made by the chloroplasts of chlorophyll-bearing organisms is the original source of all food used by plants as well as by animals and protists.[21]	*Give two reasons why we could not get along without chlorophyll-bearing plants and protists?*
1 green plants and algae make food	
In the presence of light energy, chlorophyll-bearing plants and algae convert water and carbon dioxide into glucose, a simple sugar.	*How do plants and algae make food?* (A-35)

[21]Some green plants such as sundew, venus fly-traps, and pitcher plants trap and digest insects for food in addition to being photosynthetic.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Glucose may be changed to starch where it is made.	
a roots absorb water	
Water used in photosynthesis is absorbed by plant roots from the ground water in soil.	*How do plants get the water needed for photosynthesis?* (A-36)
Tiny projections of surface cells of roots called root hairs increase the surface area of roots and thus speed up water absorption.	*What are root hairs and how do they benefit plants?* (A-37)
b stems carry water to leaves	
Stems have conducting channels that carry water from roots to leaves.	*How does water get from roots to leaves?*
c carbon dioxide enters leaves	
Carbon dioxide in the air enters leaves through tiny openings called stomata. Excess water in a plant is given off through these stomata in the leaves.[22]	*How does the carbon dioxide needed for photosynthesis get into leaves?* (A-38)
d chlorophyll in leaves	*What is the effect of soot on plants?*
The green coloring matter in leaves is chlorophyll, needed to trap the light energy essential to photosynthesis.	*What is the nature of chlorophyll?* (A-39)
e photosynthesis produces sugar and oxygen	
The oxygen is liberated as a stable molecule. This oxygen given off by photosynthesis through the stomata is the only natural means of replacing the oxygen in the environment.[23]	*What are the four conditions necessary for photosynthesis to take place?* (A-40, A-41, A-42)
Glucose is richer in energy than the carbon dioxide and water used to produce it by the amount of light energy absorbed.	*What do green plants release to the environment? (Have you thanked a green plant today?)*

[22]It should be noted that only 0.03 percent of the air is carbon dioxide. This means that 10,000 cubic feet of air must be processed to get 3 cubic feet of carbon dioxide.

[23]Photosynthesis proceeds in two phases, each of which consists of a number of complicated steps. In the first phase, the light energy trapped by chlorophyll splits the water molecule (H_2O) into hydrogen and oxygen. This is known as the "light reaction." In the second phase, carbon fixation, the hydrogen released from water is combined with carbon dioxide in a series of reactions to form a sugar-like compound with three carbon

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Oxygen is continually being removed from the environment by all forms of combustion and respiration. If it were not for the process of photosynthesis, the oxygen of the environment would eventually be reduced to a level which could no longer support life.	*Describe by illustration the oxygen cycle.*
f other foods produced by plants	
In many leaves, glucose is changed to starch, another carbohydrate. In this process, 24 molecules of glucose are linked together to produce a single large starch molecule.	*What other food products beside glucose are produced by plants?*
Glucose is changed into fats and oils by many plants. These, like carbohydrates, are compounds of carbon, hydrogen, and oxygen which are obtained from carbon dioxide and water.	
With the addition of minerals, glucose is changed into proteins and vitamins by plants.[24]	
The additional chemical elements needed to produce proteins and vitamins are contained in dissolved minerals found in soil water.	*Why do plants need minerals in addition to carbon dioxide and water?* (A-43)
Nitrogen, phosphorus, and potassium are the elements most needed by plants. These elements are provided in compounds in all commercial fertilizers.	
Dead and decaying plants and garbage can be composted thereby recycling nutrients and decreasing the need for artificial fertilizers.	*How may a compost pile be constructed?*

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atoms in its molecule ($C_3H_6O_3$). Light energy is not used in this phase.

By a series of reactions, two of the three-carbon molecules form the six-carbon sugar, glucose ($C_6H_{12}O_6$).

The three-carbon compound produced is known as phosphoglyceraldehyde (PGAL). Some authorities consider this the end product of photosynthesis, and the subsequent conversion of PGAL to glucose to be a secondary metabolic activity.

[24]Humans could more efficiently use plant proteins by eating plants

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 how fungi obtain food	
Fungi cannot make their own food and are dependent upon green plants.	*How does a fungus, such as a mushroom which lacks chlorophyll, obtain its food?* (A-44)
Fungi secrete digestive juices outside their bodies and absorb digested food material.	
3 how animals use food	
Animals, called consumers, depend on green plants for food and oxygen.	
Food is used by animals for three main purposes: (1) to supply energy, (2) to build and repair tissue, and (3) to function as body regulators.	*What are the major purposes for which animals use food?*
Water is essential to life and is needed as a solvent for the transportation of body materials.	
a nutrients in food	
All foods are composed of one, or varying proportions of several, of the following classes of nutrients: carbohydrates, fats, proteins, minerals, and vitamins.	*What are some of the nutrients present in milk?*
(1) carbohydrates	
Carbohydrates consist of sugars and starches. They are compounds of carbon, hydrogen, and oxygen in which the ratio of hydrogen to oxygen is 2:1.	*What function do carbohydrates serve in the diet?* (A-45)
Since plants store food largely in the form of carbohydrates, foods obtained from plants are rich in this class of nutrient.	

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rather then feeding them to farm animals. Algae produces 150 times more protein than farm animals. Protein produced by farm animals is about 0.2 metric tons per hectare per year. Algae yields about 30 metric tons per hectare per year.
Refer to the Department publication Living Within Our Means: Energy and Scarcity, 7-12, Activity 1, p. 27.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Carbohydrates are utilized in the body to produce energy, and excess amounts are converted to fats for storage.	
(2) fats	
Fats are also compounds of carbon, hydrogen, and oxygen, but these elements are combined in different proportions than they are in carbohydrates.[25]	*How can we tell whether or not foods contain fat?* (A-46)
Fats are utilized to produce energy, and excess amounts are stored. A unit weight of fats produces about two and one-half times as much energy as a similar unit weight of carbohydrates.	
Fats are found largely in meat and dairy products and the seeds of such plants as peanuts, corn, and soy beans.	
(3) proteins	
Proteins are the most complex of all chemical compounds containing carbon, hydrogen, oxygen, and nitrogen. Some proteins may have a variety of other elements, including sulfur, phosphorus, and iron.[26]	*What foods are rich in protein?* (A-47)
Protein molecules are formed by the joining together of many smaller units called amino acids.[27]	
Proteins are broken down into amino acids and are used to build or repair tissue or to produce energy.[28]	
(4) minerals	
Animal diets must contain certain minerals for normal growth and development.[29]	*What important minerals are needed in the human diet?*

[25]Many authorities advise that the fat content of the diet be regulated according to a person's needs and activity because of the apparent relationship between excess fat in the diet and the level of cholesterol in the blood. Cholesterol is a fatty substance normally found in all tissues of animals. When present in high levels in the blood, it is deposited on the walls of blood vessels, particularly the coronary artery that supplies blood to the heart. When cholesterol deposits thicken, they cause a condition known as atherosclerosis which may completely plug the coronary artery, causing a coronary occlusion, or

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
	How can we determine what minerals are present in various foods? (A-48)
Calcium and phosphorus are needed for the formation of bones and teeth. Iron is needed for the production of red blood corpuscles to carry oxygen to tissue cells. Iodine is needed for the proper functioning of the thyroid gland.[30]	
(5) vitamins	
A number of vitamins are needed in very small amounts to insure proper utilization of other nutrients. Vitamins A, B-complex, C, D, E, and K are known to be needed in human nutrition. Vitamin D is formed in the skin upon exposure to ultraviolet light which is present in sunlight. Vitamine K is synthesized by bacteria normally found in the large intestine.	*How can we determine what vitamins are in foods?* (A-49, A-50)
B Types of reproduction	
All living things emanate from other living things. All cases of reproduction must be either asexual (with one parent) or sexual (with two parents.	*How can we disprove the theory of spontaneous generation?*[31] (A-51)
1 asexual reproduction	
Asexual reproduction results in the formation of a new individual from a single parent.	

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heart attack.

Fats which are solid at room temperature, such as animal fats and solidified vegetable oils, are said to be saturated since they have hydrogen atoms attached at every possible point. Fish and plant oils that are liquid at room temperatures are unsaturated. Saturated fats appear to produce higher blood cholesterol levels than do unsaturated ones.

[26]Proteins cannot be stored in the animal body. Any excess of amino acids in the diet is converted by

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Offspring produced asexually are usually identical to the parent.	
a fission	
In fission, the whole organism divides into 2 or more cells, each of which grows into a complete new individual, as in the instances of bacteria, algae, and protozoa.	*How do protozoa reproduce?*
b budding	
In budding, the nucleus of the cell divides; only a small amount of cytoplasm pinches off from the parent cell.[32]	*How can we study yeast cells reproducing?* (A-52)
c spore formation	
In some protists, plants, and animals the nucleus of a cell fragments into many parts. Each part is capable of growing into a new organism.[33]	*How can spores reproduce?* (A-53)
d regeneration	
Many plants and lower animals can replace lost parts. The lost part(s) may also develop into complete new organisms. If the latter happens, reproduction has taken place.[34]	*How can animals replace lost parts?* *How can regeneration be shown?* (A-54)
e vegetative propagation	
Vegetative propagation is a type of reproduction occurring in higher plants in which a portion of a leaf, stem, or root regenerates an entire new organism, such as with bulbs, tubers, corms, and runners.	
(1) natural	*How can plants be produced without seeds?* (A-55, A-56, A-57)

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the liver into glucose and urea. The urea is removed from the blood by the kidneys. The glucose is either oxidized for energy, converted into glycogen in the liver and muscles, or converted to fat for storage in adipose tissue.

[27] Of the 20 amino acids used by humans, eight must be obtained in human diets. These are called "essential" amino acids. The remaining 12 can be manufactured by humans from the eight essential ones and from other compounds.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(2) artificial	
Certain techniques of vegetative propagation have been developed to include the use of cuttings, layering, and grafting.[35]	*How can we grow tomatoes on a potato plant?* (A-58)
Plants produced by vegetative means will be identical to the parent plant, since only one parent plant has contributed genetic material.	
2 sexual reproduction	
Two parents are required for reproduction of most higher plants and animals; this is sexual reproduction.	
A sperm cell from the male parent unites with an egg cell from the female parent; this is fertilization. A new individual develops from the fertilized egg.	
Sexual reproduction is fundamentally the same in both plants and animals.	
a flowering plants	
Most flowers produce both male and female reproductive cells.	
The male part of the flower is the stamen consisting of the anther and filament. The female part of a flower is the pistil, consisting of a stigma, style, and ovary.	*What are the main parts of a flower?* (A-59) *Discuss various types of flowers.* (A-60)
Sperm cells are produced by pollen grains formed in the anther; egg cells are produced in the ovules.	*How do pollination, fertilization, and seed development occur?* (A-61, A-62)

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[28]Animal proteins are complete proteins, for they contain all eight essential amino acids. Many plant proteins are incomplete for human needs. Although human protein needs can be met by eating the right combination of plants.

[29]Minerals are often classified into two broad categories: macronutrients (required in large quantities) and micronutrients (required in trace amounts). For both plants and animals, the principal macronutrients are: sodium, chlorine, potassium, calcium, phosphorus, and magnesium; the principal micronutrients are: iron, copper, manganese, and zinc.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Pollen from one flower is transferred to the stigma of the same flower or another flower; this is pollination.[36]	
Pollen may be transferred from one flower to another by insects as in the case of showy flowers such as sunflowers. With inconspicuous flowers, such as corn, pollination is usually accomplished by the wind.[37]	*Why do fruit growers place beehives near their orchards?*
After pollination, a sperm enters the ovule and fertilizes the egg.	
The ovule containing the fertilized egg develops into a seed.	
Each seed contains an embryo plant and a supply of food.	*What is the structure of a seed?* (A-63)
When a seed receives sufficient moisture and oxygen at a moderate temperature, the seed germinates. Stored food is digested and the partly formed embryo continues its development.	*What are some changes that take place when seeds germinate?* (A-64)
	Compare the needs of plants for seed germination, plant survival, etc., with the basic needs of humans. Describe the interactions or interrelationships between the survival of plants and of human beings.
b animals	
Egg cells are produced in an organ called the ovary of a female animal.	*What conditions are required for a fertilized hen's egg to develop into a chick?* (A-65)
Sperm cells are produced in an organ called the testis of a male animal.	

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[30]Most of the iodine in the diet is deposited in the thyroid gland where it is used in the production of thyroxin. Simple goiter is caused by a deficiency of iodine in the diet. The introduction of iodized salt is a classic example of the prevention of a deficiency disease by the introduction of a dietary supplement.

[31]For centuries it was believes that many animals could arise from non-living material by spontaneous generation. Maggots and flies were believed to originate from dead animals and frogs and rats were believed to originate from river mud. The classic experiments that disproved spontaneous generation

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
An egg is fertilized when it is penetrated by a sperm from an animal of the same species.	
A fertilized egg, when provided with the proper environment, develops into a new individual.	
(1) earthworm	
Some animals are unique (such as the earthworm) in that each individual produces both eggs and sperm (hermaphroditic). Every earthworm is capable of producing fertilized eggs from which young worms will develop. Eggs are always fertilized by sperm from another worm.[38]	
(2) fish	
Most fish eggs are deposited in the water by the female. Sperm are deposited in the water nearby by the male. Sperm swim through the water like tadpoles and fertilize many of the eggs. The eggs of fish contain enough stored food material to provide nourishment for the developing fish until it can eat.	*How do fish develop from fertilized eggs?*
In some fish (such as guppies) the eggs develop within the body of the female fish, using their own stored food supply just as those eggs that develop in the water. In these cases, the sperm are introduced into the body of the female fish so that internal fertilization can take place.	*How are guppies different from most fish in the manner in which they reproduce?* (A-33)
(3) frog	

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were performed by Francesco Redi and confirmed by Louis Pasteur.

[32]Yeast cells may reproduce by budding and by spore formation.

[33]Molds, mushrooms, some other fungi, and one group of protozoa reproduce by means of spores. An interesting example of sporulation is the protozoan which causes malaria. Within the red blood cell, each protozoan forms from 12 to 24 spores, each of which is released when the red blood cell bursts later on. The released spores infect other red cells and the process is repeated. The bursting of millions of red cells simultaneously causes the chill of malaria, and the effects of the released toxins account for the fever.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Frogs and toads reproduce in much the same way as do fish. In spite of the fact that toads and frogs spend much of their adult life on land, they must return to water to lay eggs and fertilize them.	*How do frogs and toads reproduce?*[39] (A-66)
(4) mouse	
Mouse eggs are fertilized within the body of the female and development of the young takes place there also. Since there is little food provided by the egg, nourishment of the developing young is provided from the blood stream of the mother mammal.	*How does a typical mammal reproduce?*
C Life cycles of protists, plants, and animals	
The life cycle of an organism is the series of changes it goes through in its own development and in producing more of its kind.	
1 in protists	
a bread mold	*What is the life cycle of common bread mold?*[40] (A-53)
2 in plants	
a radish	
The life cycle of a radish plant is typical of that of all flowering plants.	*What is the life cycle of a typical flowering plant?* (A-67)
3 in animals	
a fruit fly	
Typically, as in the fruit fly, insect eggs are fertilized by sperm inside the body of the female.[41]	*What is the life cycle of a typical insect?* (A-68)

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[34]Reproduction by regeneration is well developed in sponges, planaria, and starfish.

In humans, the power of regeneration is limited to the production of new tissue to heal wounds.

[35]Among the advantages of vegetative reproduction is the production of mature plants more quickly than by seed, and the propagation of plants that do not produce seed or whose seed would give rise to plants differing from, and less valuable to humans, than the parental stock.

Many plants, such as geraniums, seedless grapes, and willow can be grown from stem cuttings planted in

b frog

Frog and toad eggs are deposited in pond waters in early spring. Sperm are also deposited in the pond by the males. Sperm swim to the nearby eggs, fertilizing them. The fertilized eggs soon hatch into tadpoles, with gills and fin-like tails. After a time, a jaw and legs develop. At the same time, the gills and tail disappear and the adult toad or frog is formed.

What is the life cycle of a frog? (A-66)

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the ground. Others, such as climbing roses and raspberries can be propagated by layering. This amounts to a stem cutting planted in the ground, yet still attached to the parent plant.

The cuttings of most trees will not grow roots in the ground and must be grafted. In grafting, a stem cutting is, in effect, planted in the roots of a closely related plant instead of in the ground.

[36]In general, self-pollination is prevented because the sperm and egg of the same flower do not mature at the same time.

[37]Wind-pollinated plants are almost exclusively the cause of hay fever. People subject to hay fever are allergic to the pollen of some plants.

[38]The smooth band around the earthworm (the clitellum) functions in reproduction. Sperm, received from another worm, are stored in structures called seminal receptacles, that have openings to the outside. Ovaries also have openings to the outside, somewhat posterior to the openings of the seminal receptacles. After mating, the clitellum secretes a mucous sheath which slips forward along the worm. Fertilization occurs when eggs and sperm are released into this sheath. The sheath slips off forming a cocoon. The embryos develop within this cocoon.

[39]Toad eggs occur in strings, whereas frog eggs are found in large masses.

[40]The life cycle of bread mold starts with the germination of a spore. As a spore develops, it produces thread-like structures called hyphae. Some of these penetrate the food on which the mold is growing, secreting digestive juices and absorbing the products of digestion. Other hyphae produce spore cases in which are developed more spores for another generation.

[41]Fruit fly eggs are deposited on the surface of ripe fruit. After a few days they hatch into worm-like larvae which feed on the fruit and its juices. In about a week the larva changes into a pupa, from which in several days emerges the adult fly. In culturing fruit flies, yeast is essential. Apparently there are some vitamins or other dietary elements present in the yeast which are essential for fruit fly nutrition. In nature, these are probably supplied by wild yeasts whose spores land on the ripe fruit and grow.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
III Ecology	
Ecology is concerned with understanding the complex interrelationships between living organisms and their environment, and among the organisms themselves.	
Ecosystems are groups of organisms interacting with each other and their environment.	
Any one of an environment's components such as space, water, air, food, or energy may become a limiting factor.	
A Interdependence of living things	
No organism or group of organisms can exist without influencing, or being influenced by, other living things and the surrounding environment.[42]	*How can the interdependence of living things be observed?* (A-11)
Interdependence of all living things dictates the manner in which and the extent to which resources may be used.	
1 natural communities	
All organisms existing as interacting inhabitants in any given area form a natural community.[43]	*How can environmental conditions in a community be studied?* (A-68)
a types	
Natural communities may be classified in a variety of ways.	*In what ways do aquatic and terrestrial communities differ?* (A-69, A-70, A-71)
(1) based on habitat	*Given a habitat, describe its components.*

[42]In any particular area organisms react among themselves and with their environment. Relationships are established which form the foundations of intricate dynamic systems called natural communities. Some common relationships are: predation, parasitism, commensalism, mutualism, scavenging, and competition. Refer to the Department publication Environmental Education Curriculum Infusion Units for grades 7-12, pp. 77-81 (Sponge Simulation Activity: Interdependence).

[43]Spatial boundaries of natural communities are not clearly defined. Ordinarily one or more major environmental factors

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Sometimes it is convenient to classify communities on the basis of physical conditions of the environment.[44]	
Communities influenced chiefly by water are aquatic, while terrestrial communities are influenced chiefly by land.	
(2) major climax communities (biomes)	
Communities may also be classified on the basis of dominant vegetation which is usually determined by climate.[45]	
The major climax communities (biomes) that occupy broad land regions are tundra, taiga, deciduous forest, grassland, desert, and rain forest.	*Describe a major climax community.*
b biological succession	
Natural communities change in an orderly, predictable sequence of events, and over a period of time one community is changed into another quite different community.[46]	*What are some evidences that natural communities undergo change?* (A-72)
Succession is due to changes in the environment.	*What factors may alter or impede a natural succession?*
Members of each community foster conditions which encourage growth of other kinds of organisms at the expense of their own offspring.	
In any given area various stages of succession occur side by side, and exhibit transition regions between two specific stages.	
(1) primary	

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determine the character of a community. Consequently, for purposes of convenience, community limits may be arbitrary. The bounds of a community may be fixed by the opinion, or purpose of the scientist.

[44]The first step in establishing the various types of natural communities is classifying them as either aquatic or terrestrial. The degree of specificity may be as broad or as narrow as the investigator requires.

[45]Major land communities are defined by the climax plant communities they are able to support. Climax plant communities are controlled chiefly by climate. In these

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Primary successions occur whenever previously uninhabited areas begin to support life.	
(2) secondary	
Secondary successions occur from an interruption of primary successions.	
Secondary successions occur on areas modified by humans or by natural occurrences where the influence of previous organisms may affect the succession.	
B Natural balance within the community	
Members of a natural community tend to maintain a compensating equilibrium among themselves.[47]	
The equilibrium is the result of complex interactions among community members involving the exchange of matter and energy among organisms or the community, and between the organisms and their environment.	
1 energy flow	
Energy enters community cycles when green plants (producers) capture light energy during photosynthesis.[48]	*What are some evidences that show that matter and energy are exchanged among members of a community?* (A-73)
Plants use some energy themselves and some is stored in food substances formed by the plants.	
The energy of food is transferred to animals when plants are eaten.	

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communities the climax vegetation is usually dominant; that is, the climax vegetation is most influential in conversion of energy and in modification of the environment.

[46]Natural communities are not definitely fixed in time. With passage of time, there occurs a directional sequence of changes until ultimately a more or less static community becomes established. It is only the offspring of climax organisms which are able to survive in conditions fostered by parents. During the sequence of changes, as the plants change, there is an accompanying change of animal inhabitants. The time required for a successional sequence to occur

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Whenever energy is transferred from one organism to another, some is lost (usually in the form of heat) and cannot be used further in the community.	
The flow of energy is in one direction, and the supply of available energy must be replenished continually if the community is to survive.	
2 matter flow	
The flow of matter in natural communities forms a cycle.[49]	
Living organisms are composed of the same materials which make up the earth.	
Plants use materials from air and soil to produce food substances.	
When plants are eaten by animals such material becomes part of the animals' bodies[50]; and when organisms die, decay returns the matter of their bodies to the air or soil whence it becomes available for reuse by new organisms.	
3 community organization	
Energy and matter flow through natural communities in pathways called food chains.	
All food chains begin with green plants since they are the only organisms which can convert radiant energy into a form which animals can utilize.	
Inhabitants may be classified into three general groups according to function.	*What are some of the activities of organisms in a community?* (A-74)

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is extremely variable.

[47]At any given time a community tends to exhibit equilibrium. Some organisms may be more abundant than others. Conditions of abundance may vary in more or less rhythmical fashion. However, no one type of organism completely controls the community. From one viewpoint the various components fit together harmoniously; from another they are in constant turmoil. There is some similarity to the dynamic stability of a whirlpool. Through an intricate network of interactions, the organisms tend to hold one another in check. The processes by which this balance is accomplished involve the complex flow of matter

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
a producer organisms	
Some organisms are able to convert radiant energy of light into chemical energy which is stored in foods. Such chemical energy is then usable by all members of the community. The most abundant producers are chlorophyll-bearing algae and green plants. These producers form the foundation of any community since other organisms are able to use only chemical energy.	
b consumer organisms	
Some organisms must depend upon the chemical energy made by producers, and there are many variations of such dependence.[50]	*How efficiently do consumer organisms utilize food?* (A-76)
c decomposer organisms	
Some organisms break down complex substances of dead organisms in such a way as to release simple substances into the environment. These simpler substances then become resources for producer organisms. This feature of reuse is important since essential substances exist in limited amounts.[51]	
4 disturbance of balance	
Natural balance may be disturbed in various ways.	*What can we do to learn about equilibrium in communities?* (A-78)
a natural	
Some disturbances are natural occurrences - floods, fires, earthquakes, climatic change, and disease.	

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and energy from the environment through the organisms back to the environment.

[48]Activity is characteristic of life and requires expenditure of energy. Energy which runs natural communities is derived from sunlight. The energy passes temporarily through various components of the community and is ultimately released into the nonliving world in a form which organisms are unable to utilize. Within the natural communities, transfers of energy are in conformity with both laws of thermodynamics.

[49]Present various biogeochemical cycles; for example, hydrogen, carbon, nitrogen, and calcium.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
b human-made	
Some disturbances are the result of the activity of humans.	*Give several specific examples of how humans disturb the balance of nature.*
Humans alter natural communities and often create disturbances that are undesirable, or even harmful, to their own welfare.[52]	
C Resource conservation	
Ethically, humans are stewards rather than owners of the resource base.	
The Earth's resources and recycling system can support a limited number of people; therefore, as populations increase and as resource supplies decrease, the freedom of humans to use resources decreases.	*Cite specific examples of how the resources used and produced by all living things illustrate the interdependence of all living things.*
Humans have exercised a presumed right to exploit the environment with little regard for their responsibility to preserve it.	
Man is faced with serious shortages, or exhasution, of natural resources upon which his continued welfare depends.[53]	*How may humans improve their contribution to, or lessen their impact upon, the natural environment through recycling and other conservation practices?*
Soil, trees, and water are classified as renewable resources, but, because their renewal or revitalization requires a major investment in time and effort, they may be more realistically considered depletable resources.	
1 necessity of conservation programs	
The majority of resource problems arise from disturbances of the natural equilibrium of biological succession by humans.	*Why are programs of conservation necessary?*[54] (A-11)

The topic of radioactive comtamination of these cycles may be explored.

[50]When consumers utilize foods, the energy contained therein is degraded. For example, only about 10 percent of the energy at one feeding level moves to the next higher level. Thus, 100 kilograms of corn produces 10 kilograms of beef cattle and this in turn produces 1 kilogram of human. Consequently, the most efficient food chains are those which are short.

[51]Decomposition converts complex organic substances into carbon dioxide, water, and simple nitrogen compounds. It also reduces to a minimum the energy content of

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
A steadily increasing human population, a diminishing supply of resources, and man's wasteful attitudes make an organized intelligent program of conservation imperative.	*Select a human population (community, state, nation, world) and depict its growth over a period of decades by means of a graph.*
2 soil resources	
Human survival depends upon good soil.[55]	*How long does it take for topsoil to form?*
The soil is the storehouse of elements from which green plants make food thereby making plants the source of food for all animals, including humans.	*How can the productivity of soil be extended?*
a nature	
(1) formation	
Development of fertile soil requires very long periods of time since soil is formed by the mixing of finely pulverized rock with humus.	*How is soil formed?* (A-79, A-80)
Many processes which result in the breaking up of rock and formation of humus are directly associated with the flow of matter and energy through natural communities.	
(2) composition	
Soil is a mixture of minerals, humus, air, water, and living organisms.	*Of what is soil commonly composed?* (A-81)
(3) structure	
Soils usually occur in well-defined layers: leaf litter, decaying litter, humus, topsoil, subsoil, and parent material.	*How are components of soil arranged?* (A-82, A-83)

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the compounds. These simpler substances are usable by producers in the synthesis of nutrients. In a sense, the decomposers tie the ends of the matter cycles together making continuation of life possible.

[52]Humans establish artificial communities which serve their own interests, at least temporarily. Removal of forests produces lumber and clears land for agricultural use, but it also creates conditions leading to erosion, floods, and the reduction of wildlife. Extensive areas of cultivated land provide crop foods, but also create opportunities for real "population explosions" of insect pests. The use of pesticides kills harmful insects,

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
b damage to soil	
Soils are damaged mainly through erosion and depletion. Damage is often the result of human activity.	*How is soil damaged?* (A-84)
When the population is small, the only persons affected are those who used the land. As the population increase misuse of the land affects everyone.	
(1) erosion	
Erosion is chiefly the result of either wind or water.[56]	*Give some specific examples of the effects of erosion by wind and water.*
(2) depletion	
Depletion is the result of overcropping, leaching, and of mismanagement. (Much prime agricultural land is being destroyed by land developers and through ubanization[57]).	*What steps may be taken to better manage the agricultural land resource?*
c methods of conservation	
(1) erosion control	
Erosion may be prevented through the use of cover crops, contour plowing, strip cropping, diversion ditches, windbreaks, terraces, mulches, and gully control.	*How may soil be conserved?* (A-85, A-86)
(2) depletion control	*Discuss the demands placed on agricultural lands around a metropolis.*
Some methods of soil conservation must be employed to restore the nutrient components of the soil. Soil depletion may be minimized by the use of crop rotation, green manure crops, fallowing, liming, and chemical fertilizers.	

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but may also destroy valuable wildlife and many beneficial insects (99.9% of insects are harmless or helpful to humans). The construction of reservoirs and highways provides important public facilities, but destroys irreplaceable wildlife habitats. The use of detergents is an aid to cleanliness, but has resulted in serious pollution of ground water. Refer to the Department publication Environmental Education Curriculum Infusion Units for grades 7-12, pp. 97-101 (Bugs in Our Biosphere).

[56] From their environments living organisms continually draw a supply of matter and energy. Each kind of organism tends to utilize environmental resources to a maximum.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
3 water resources	
Water conservation is closely associated with the conservation of soil, forests, and wildlife.[58]	*How can we gain a better understanding of the problems of water conservation?*
a importance of water	
Water is not gained or lost on Earth. The supply is finite and constantly recycled.	*Of what importance and use is water?* (A-87, A-88)
Humans require water for a great variety of activities and their needs for water are steadily increasing while the supply remains more or less stable.	
Less than half the water used by humans is returned to the environment in a useable condition.	*How can we increase the amount of useable water in the environment?*
(5) recreational use	
The most common uses of water are agricultural, domestic, industrial, hydro-electric, recreational, and for the disposal of waste.	
b methods of conservation	
Methods of water conservation are designed to: (1) make better use of the available supply, (2) prevent pollution, and (3) retain a greater percentage of runoff.	*What can be done to help conserve water?* (A-89)
Water conservation is accomplished through reservoirs, reforestation, watershed management, pollution control, and through filtration/purification processes.	*How are community water supplies purified?* *How can family water supplies be made safe for drinking during times of disaster?*

Hence organisms tend to increase and disperse. Unlimited increase and dispersion are actually checked by limitation of the environment, and/or competition. Such natural limiting does not reduce use of resources, but rather establishes the ratio of various species which any given area can support. There is no reason to believe that these principles do not apply to humans.

[54]Problems of resource supply arise because man by his activities acutually reduces the capacity of the environment. Natural cycles ordinarily return matter to the environment at a rate about equal to rate of removal. Difficulties arise when man interfers with the

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
4 forest resources	
Forest conservation is closely associated with the conservation of soil, water, and wildlife.	*Describe the importance of forest resources?*[59] (A-90)
a value and uses of forests	
Forests are of great value for wood products and lumber, soil and water conservation, wildlife habitat, beauty, and recreation.	
b some factors of destruction	
The greatest loss of forest resources is through fire, misuse and waste, and the ravages of insects and disease, all of which are largely due, directly or indirectly, to human activity.	*What are some ways in which forests are destroyed?* (A-91)
c methods of conservation	
Forest conservation is achieved through fire protection and prevention, reforestation, insect and disease control, selective cutting, block cutting, thinning and pruning, and through more efficient utilization of the resource itself, which includes the recycling of forest products.[60]	*In what ways may forest conservation be carried on?* (A-92, A-93)
5 wildlife resources	
Wildlife is valuable in many ways to humans, although no longer a primary source of food.[61]	*What can we do to provide improved understanding of wildlife and its conservation?*[62] A-94, A-31)
a importance of wildlife	

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cycles in such a way that matter is removed faster than it can be replaced. Successful conservation must involve recognition that it is impossible to get more out of a biological cycle than goes into it. Refer to the Department publication Environmental Education Curriculum Unfusion Units for grades 7-12, pp. 23-77 (Overpopulation: A Drain on Resources).

[55]Most agriculture takes place on a few centimeters of topsoil. Only 10 percent of the Earth's surface is useful for agriculture. Conservation of soil is closely linked to conservation of all other forms of resources.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
The wildlife resource is important for natural balance (Humans have failed to recognize the importance of individual species in the balance of nature.), food and fur, insect control, recreation, and aesthetics.	
b methods of conservation	
To succeed, any method of wildlife conservation must recognize that wildlife needs food and cover (principally vegetation).	
Methods of wildlife conservation are legislation, habitat improvement, restocking, game refuges and management areas, and the introduction of exotic species.	*What is an endangered species? Give examples of species currently endangered.*
6 mineral resources	
The nonrenewable resource base of mineral elements is considered finite, and depletion can only be slowed by altered priorities, new demographic considerations, improved conservation practices, and vigorous recycling procedures.	*Of What importance are our mineral resources?*
D Environmental imperatives	
Interdependence of all living things dictates the manner in which, and the extent to which, resources may be used by individuals and society.	
1 for individuals	
Individuals should become well informed about the best ways to manage and conserve our resources.	*What are some of the best ways individuals may conserve natural resources?*

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[56]Steep lands (slopes of over 12°) should not be cultivated or developed but should be forested.

[57]Prime agricultural soils represent the highest level of agricultural productivity. Such lands are difficult to defend against land development and urbanization.

[58]Annually the United States receives approximately 76 cm of rainfall. Distribution is very uneven, from less than 25 cm to more than 300 cm. Almost half of this supply is returned to the water cycle by evaporation. Of the remaining half, about one-third is used in plant metabolism, about one-third becomes ground water, and about one-third becomes run-off.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Choices between essentials and nonessentials are often in conflict. Individuals tend to select short-term economic goals, often at the expense of greater long-term environmental benefits.	*Why is it important to be able to distinguish between essential and nonessential needs? How can you make these distinctions?*
2 for societies The material welfare and aspirations of a culture largely determines the use and management of natural resources. Historically, cultures with high technological development have used disproportionately more natural resources, than those with lower levels of technological development. The limited nature of productive resources makes it imperative that a society define its own economic objectives in terms of environmental reality.	*In what ways has the United States been most wasteful in depleting its natural resources?*

Ecologically the most efficient techniques of water conservation should strive to maintain a land surface which can absorb water efficiently enough to permit subsurface storage.

[59]The economic importance of forests is directly related to soil, water, and wildlife. Over 800 years ago Europeans recognized the necessity for forest management, but it was not until about 1890 that the United States began any conscious attempts. Even today it is only the Federal and state governments and large commercial interests that are practicing good forest management.

[60]Refer to the Department publication Environmental Education Curriculum Infusion Units for grades 7-12, pp. 69-72 (Better Utilization of Forests and Wood Products).

[61]Aside from the economic aspects of wildlife, in terms of hunting and fishing, the major consideration of the wildlife resource is that natural ecosystems and subsystems be maintained. The aesthetic importance of wildlife should not be overlooked. Hunters and fishermen are outnumbered about 8:1 by people who enjoy watching animals.

[62]Extinction is a natural occurrence. However, human activities have speeded up the rate of extinction. It may be difficult to argue a case for any one particular species, but the question which should be considered might well be, "Is there no room on this planet for anything except man, and those species which can tolerate him?" Some of the species which have been able to tolerate humans include cockroaches, ants, rats, and starlings.

APPENDIX - LEARNING ACTIVITIES

A-1. Some Characteristics Common to All Living Things [1, 5, 14]

(a) Provide each pupil or small group of pupils with a goldfish in a container of water. A grasshopper or other insect can also be used. Have pupils observe for a period of 10 or 15 minutes, recording everything they observe that indicates the creature is a living thing.

(b) Provide each pupil or small group of pupils with a bean or other seedling. Have daily observations and records made over a period of several days. Records should be kept of observations that indicate the seedling is a living thing.

(c) Compare the data gathered in (a) and (b) above, to see what characteristics of living things are common to both plants and animals.

A-2. Movement in Plants [14 ,10 ,8]

Put a potted plant, such as a geranium or *Coleus*, on a window sill. After the leaves have faced the window, turn it so that the leaves are facing directly away from the window. Note how long it takes until the leaves are all again facing the window.

Call attention to the bending of the petioles supporting the leaves and relate this to the differential growth that is the cause of most plant movements.

A-3. Movement Within Cells [4, 6, 1]

The cytoplasm in living, active cells is a dynamic moving material. This movement, called cyclosis, may be observed in *Elodea* leaf cells.

Mount a leaf from the growing tip of a plant, rightside up, in a drop of warm water on a microscope slide. Add a cover slip. Focus on the upper layer of cells near the midrib and look for movement of chloroplasts. This will require the high power of the microscope.

Movement may be speeded up with a warming light. In reality, the chloroplasts are not moving under their own power, but are being carried along with the movement of the cytoplasm in which they are suspended.

A-4. Animals Need a Constant and Ample Supply of Food [15, 16, 17]

The fact that animals need a constant and ample supply of food for normal activity and growth can be dramatically illustrated with a large litter of young white rats, part of which are fed a restricted diet.

Secure a litter of six or eight rats, and as soon as they have been fully weaned, divide them into two groups of three or four. Working with litter mates will guarantee their heredity to be as identical as possible. Thus, any results noted can reasonably be expected to be due to the experimental conditions provided.

Feed one group of rats (the control group) as much of a dog biscuit as they will eat each day. Most dog biscuits provide a complete diet of all nutrients required for rats as well as for dogs. About 6 gm of food for each rat is a good amount with which to start. The amount fed will have to be adjusted as the experiment progresses so that the animals just finish the food available each day. Feed the experimental group just half the amount given to the control group. See that all animals, experimentals as well as controls, have water available at all times.

Weigh each rat daily and record the growth of all rats on a single multiple-line graph. Different colored lines may be used for the two groups of rats. Also record any differences in behavior of the animals in the two groups. The amounts of food demanded by the two groups should be compared as well as their growth rates. Be sure to note on the record graph any changes in experimental conditions. As soon as definite differences have been noted in the growth rates of the animals in the two groups, the experimental animals can be fed all the dog biscuit they will eat.

It is interesting to note that recent experimental evidence indicates a longer life span for the underfed animals than for adequately or overfed animals.

A-5. Seeds Need Oxygen to Grow [11, 16, 17]

Wet the insides of two jars, such as baby food jars, by filling them with water and emptying them. Put iron filings in one and rotate the jar so that the iron filings stick to the inside of the jar, discarding any excess. Do the same thing with small seeds, such as those of radish or mustard, to both jars. One jar now has seeds alone stuck to the wet inside walls, while the other has both seeds and iron filings. Invert both jars in dishes of water. The water will provide a sealed atmosphere in each jar and at the same time provide an indication of any changes in volume of the atmospheres in the jars.

In a short time the water will rise in the jar containing the iron filings and seeds, and the iron will become a rusty color. Oxygen is thus not available in the atmosphere of the jar with the iron, which will prevent the germination of the seeds. Seeds in the other jar will germinate in a day or two, but there will be no corresponding rise in the water level. Carbon dioxide production about equals oxygen uptake by the seeds, resulting in a rather constant atmospheric pressure in the jar.

It should be emphasized in class discussion that the experimental factor here is the presence of oxygen. The jar with the iron filings is, therefore, the control, for it lacks the experimental factor.

A-6. Respiration in Fish [9, 10, 2]

Many pupils are under the impression that it is the oxygen combined in water that is used by fish in respiration. Since fish, like most other animals, are aerobic, free oxygen is required for their respiration. This is normally found dissolved in the water. Respiratory distress can be quickly produced in a goldfish by removing the dissolved air from the water surrounding the fish.

Fill two Florence flasks of 500 cc or 1000 cc size to the neck with tapwater and bring each to a rolling boil. This will remove all dissolved air from the water. Pour the water from one to another container and after agitating it well to aerate it, replace it in the flask. Leave the water in the other flask undisturbed. Allow to cool to room temperature.

You now have two flasks of water, identical except that one contains dissolved air while the other does not. Gently drop a small goldfish into each flask and observe the behavior of each. As soon as the fish in the unaerated water becomes motionless, bubble some air into the water with an aquarium pump or by blowing into the water through a straw. If this is done promptly, the fish can be revived quickly.

A-7. Plant Growth and Competition [17, 13, 12]

The effects on plant growth of soil water deficiency and plant competition can be demonstrated in the laboratory quite easily.

Fill four identical flowerpots with potting soil. In each, plant a seedling, such as a sunflower or a tomato. Number the pots 1 to 4. From a graduate, supply the seedling in pot number 1 with 5 ml of water whenever it shows signs of wilting.

Each time pot number 1 is watered, put twice this amount in pot number 2; four times as much in pot number 3; eight times as much in pot number 4. At the end of several weeks, note the effect on growth of the varying amounts of water.

A-8. Relationship of Goldfish Body Activity to Water Temperature [15, 13, 5]

The rate of body activity of a coldblooded animal such as a goldfish can be determined by counting the rate at which it opens its mouth to take in water over its gills. The rate at which the operculum, or gill cover, opens can also be measured.

With a goldfish in a liter container of water together with a thermometer, determine its rate of body activity as above. A minute is suggested as the interval of time to use in counting the rate of opening of the mouth or operculum.

Put the container with the fish in a refrigerator. At 10-minute intervals remove the container from the refrigerator. Note the temperature of the water and determine the rate of body activity of the fish. Graph the data from room temperature to 5°C.

A-9. Growth in Plants [19, 18, 22]

(a) Call attention to the one-sided growth of house plants. Turn the plants occasionally and call attention to the changed directions of growth.

(b) Notice how the shapes of trees near the school are affected by obstructions to the light. The sides of trees near buildings, for instance, show less branching than the sides exposed to sunlight.

(c) Plant fast growing seeds such as radish, lentil or oat seeds in four flower pots and keep them in the dark until the seedlings are 2 centimeters or more tall. Place one of the pots in a sunny window and notice how quickly the seedlings bend toward the light.

A-10. Response of Living Things to Stimuli [16, 14, 11]

Place several houseflies or fruit flies in a piece of large bore glass tubing 50 cm or more in length. Stopper both ends of the tube. Make a sleeve of black paper half the length of the tube and fit it so that it slides back and forth on the tube. Determine whether the flies are attracted to the lighted or dark end of the tube. Move the sleeve several times and notice the response of the flies.

A-11. Conducting Fieldtrips [14, 2, 1]

In many schools it is not practicable to take long fieldtrips. The most successful fieldtrips, however, are often those that extend only to some point on the school grounds and are centered around the observation of some single object or phenomenon. Such a trip might not require more than 5 or 10 minutes. In planning a fieldtrip, either long or short, the following suggestions should be helpful.

A Advance Preparation for the Trip

1 Each trip should have a definite objective. For instance, the objective might be to observe the loosening of leaves and the formation of leaf scars on some tree near the school building.
2 The trip leader or teacher should go to the place to be visited in advance of the trip. Plans for conducting the observations should be made on the spot. It is helpful to make a few notes for a short talk or to jot down additional items that might be called to pupils' attention, for example: mosses, lichens or evidence of insects on the bark of a tree; nearby trees with leaves falling or not yet ready to fall.
3 Preliminary instructions and discussion should include:
  a Purpose of trip and destination
  b Time of departure and return
  c Appropriate wearing apparel (coats, rubbers)
  d Some specific things to observe, collect, or discover
  e Equipment needed, if any (magnifying glasses, containers)
  f Safety precautions
  g Necessity of keeping together and with the leader

B Conducting the Trip

1 Be sure that comments on observations are simple and adapted to the level of the group
2 Encourage questions and be sure that all hear and understand the questions and answers.
3 Repeat all important points again and again.
4 Give more than facts and names; if possible, present comments in story form.
5 Make the most of unexpected occurrences and observations volunteered by the group.
6 Emphasize principles of conservation by pointing out interrelationships of the plants and animals observed.

C Summary of the Trip

Discuss the highlights and repeat the important findings. If conditions permit, the best time to do this is on the spot. After observations have been made, pupils can be seated in a circle. Otherwise the summary can be made immediately after returning from the trip. For some trips oral or written reports by pupils are appropriate.

A-12. Studying Habitats [17, 14, 13]

(a) Take a 5-or 10-minute fieldtrip beginning at an outside wall of the school building where there is a base planting of bushes. Route the trip across a path or sidewalk and end it at the edge of the school grounds. The purpose of this fieldtrip will be to discover the various habitats that exist on the school grounds. The bushes next to the building are really a miniature forest; the lawn is a wide prairie; the path or sidewalk is a dry desert. In each of these habitats there will be different plants and animals. In summarizing the trip, ask pupils to tell the things about each habitat that make it different from the others.

(b) A more careful and thorough study of the different habitats on the school grounds can be made after the preliminary fieldtrip. This activity is suitable for small group projects. A survey can be made of the entire school grounds to discover additional places where conditions differ from those of the base planting, the lawn and the walks. For instance, there will usually be one unused corner of the school grounds where the grass is not mowed. The plants, animals, and general conditions along the shaded north side of the building will differ from those on the sunny south side. Conditions directly under a tree will differ from those in the open lawn. Hedges and border plantings in the open differ from plantings next to the building. Ask the class to decide how many different kinds of habitats there actually are on the school grounds.

(c) Observation of the various habitats on the school grounds will reveal a surprising variety of animal life and evidence of animal activities. Study some of the insects found in various places. Look for burrows and mounds made by mice, moles, and shrews. Look for spiders and spider webs. Lift up stones or other objects that have lain on the ground for some time and look for sow bugs, millipedes, and ants. Examine trees and bushes for living insects and leaves that have been partly eaten in different ways.

Watch for birds and try to observe what they are feeding on. Look for mouse trails in weedy places. Look for ants and ant hills in dry, sandy places. Ask pupils to compile a summary list of the animals and evidence of animal activities found on the school grounds and to indicate where each observation was made. The list will show that each animal is commonly found in certain places and not in others.

(d) Further observation of the different habitats on the school grounds will show that particular kinds of plants commonly grow in certain places and not in others. Compare the plants growing in shady places with those that grow in sunny places. Find rosette plants with their leaves spread out close to the ground on the lawn. Notice what plants are able to survive in well-trodden places. Compare the vegetation growing on fertile soil with that growing on poorer soil.

(e) Summarize the information gathered from the study of the school grounds in the form of a habitat map. Indicate the areas that are similar to deserts, prairies, shady woodland, open woodland, cultivated land, and waste land. Make a key for the map listing the plants and animals found in each of these habitats.

A-13. Nature Bulletin Board [14, 2, 1]

A nature bulletin board can be used to display pictures illustrating protective coloration, mimicry, and other types of adaptation. Pupils should be encouraged to contribute to such a bulletin board.

A-14. Goldfish Adaptations [2, 1, 14]

Almost every classroom can maintain an aquarium with fish of some kind. Carefully observe how the fish swim. Notice how the fins and tail are used. Observe the mouth and gill cover movements of the fish. Note that water goes into the mouth and then the gill covers open while the water comes out. Also observe that the underside of a fish is usually lighter in color than the rest of the fish. This device helps the fish blend into its surroundings and makes the fish more difficult to see from above or from below.

A-15. Water Supports Water Plants [17, 16, 9]

Compare the leafstalks of plants from the classroom aquarium with those of a land plant such as goldenrod. The leafstalks of the water will be softer, lacking the woody tissues of the land plant. The water plant is supported by the water and does not need the added stiffening to hold its leaves up to the sunlight. Four kinds of water plants that grow well in aquariums are shown in the diagram on the following page.

A-16. Soil Habitats of Animals [14, 11, 10]

(a) Several days after rain, mark off two equal-sized squares in a fertile area — the school lawn, for example. Water one square well and do not water the other square. The earthworms in the watered square should come up to the surface. Dig into each square and find out how much closer to the surface the worms are in the plot that has been watered. Follow this demonstration with a discussion of the value of the earthworm tunnels which are channels for air and water.

(b) Take a fieldtrip to locate an ant hill. Usually colonies can be found on the school grounds. Ask pupils to try to locate several ant hills. Then organize a fieldtrip to visit them. Observe the activity of the ants, some bringing food, others perhaps removing waste materials. See how they seem to accelerate their activities as they become aware of human beings near their colony. Dig into the ant hill with a trowel or shovel. If the nest is under a stone, lift the stone. Look for eggs, larvae, and pupae.

(c) Scoop up some of the adults and pupae. Place them in a jar along with some soil. In the classroom set the jar in a pail of water so that the ants will not escape when you remove the lid. Keep the colony covered with a large box when it is not being observed. If kept dark in this way the ants will construct tunnels along the glass sides of the jar. Return to the disturbed ant hill and see how the ants repair the damage done to their nest.

A-17. Soil Samples [7, 8, 11]

Obtain a sample of topsoil in the following way. Push a shovel or spade vertically into the soil to a depth of about 15 centimeters. Now make three other cuts in the form of a 15-centimeter square. Lift out a cube of soil about 15 centimeters in each dimension and set it on a spread-out newspaper. Sift this soil onto another newspaper, through a wire screen, watching closely for any insects or other small animals that may be found.

Place these in a glass jar as they are discovered. Use the sifted soil to fill the hole where the soil sample was obtained. Examine three other samples of soil in different locations in a similar way. Note the number and kinds of animals found. The four 15-centimeter cubes of soil make a total surface area of about one square foot. An estimate of the number of small animals in a 15-centimeter layer of an acre of topsoil can be made by multiplying the number found by 43,560, the number of square feet in an acre.

A-18. Adaptations of Plants in Soil [8, 9, 10]

Wash the soil from a 15-centimeter square of grassy sod. This can be done easily by placing it in a pail of water and swishing it gently up and down. Notice the thick mass of intertwined grass roots. Locate the roots of plants other than grasses. Some of these will have taproots that penetrate quite deeply into the soil. The varying depths to which roots penetrate make it possible for several kinds of plants to grow very close together.

A-19. Feather Adaptation [4, 6, 1]

The study of a wing feather from a chicken, pigeon, or other bird affords a good opportunity for observing the adaptation of a feather for its work. Pupils should be led to notice its extreme lightness, flexibility and strength. Examine the feather with a hand lens or microscope under low power and see the interlocked barbs which prevent air from passing through the flat part of the feather.

A-20. Need for Organisms to Have Names [8, 18]

Students need help in discovering the convenience of names, especially biological names. In this exercise, students attempt to express ideas without using certain names. It should help them to understand that names are timesaving symbols that replace much longer descriptions.

Prior to class time, write a number of simple messages, each on a separate filing card, that contain the names of objects or persons familiar to the pupils. For example: (1) I broke an egg. (2) Did you hear the fire alarm? (3) You will find it in the dictionary. (4) Meet me at Bob's locker. (Underline the names, as in the examples given.)

Divide the class into groups of several pupils each. Each group is to be given one of the cards, which the pupils are to rewrite, using descriptions rather than the underlined words.

"The pig is eating corn." Pupils should not substitute "hog" for "pig" nor "maize" for "corn." An acceptable rewriting might be, "The four-legged animal with short hair, a twisted tail, small eyes, and an under-slung jaw is eating something that is yellow, shaped like a club, and made of pieces about one-half centimeter long.

A-21. Characteristics and Their Relation to Classification [2, 18]

To understand the classification of organisms, pupils must first have an understanding of the meaning of the terms "traits" and "characteristics" and how they are used in identifying organisms.

(a) Identifying Paper Figures. Divide the class into small groups. Provide each group with a set of 16 numbered figures as described in the list below. The set consists of circles, diamonds, and rectangles of two sizes and two colors. The rectangles also have two kinds of edges — straight and wavy. Have each group list the numbers 1 through 16 in order on a sheet of paper. After each number should be written a description of the figure bearing that number.

After this has been completed, individual pupils should read the description of a figure, without revealing the number of the figure being described. Pupils from other groups should attempt to identify by number the figure being described.

A set of paper figures includes:

1. 1 red diamond — edges 6 cm long
2. 1 red diamond — edges 4 cm long
3. 1 yellow diamond — edges 6 cm long
4. 1 yellow diamond — edges 3 cm long
5. 1 red circle — 6 cm in diameter
6. 1 red circle — 4 cm in diameter
7. 1 yellow circle — 6 cm in diameter
8. 1 yellow circle — 4 cm in diameter
9. 1 red rectangle — 5 cm x 9 cm — edges pinked
10. 1 red rectangle — 2 cm x 5 cm — edges pinked
11. 1 yellow rectangle — 5 cm x 9 cm — edges pinked
12. 1 yellow rectangle — 2 cm x 5 cm — edges pinked
13. 1 red rectangle — 5 cm x 9 cm — edges straight
14. 1 red rectangle — 2 cm x 5 cm — edges straight
15. 1 yellow rectangle — 5 cm x 9 cm — edges straight
16. 1 yellow rectangle — 2 cm x 5 cm — edges straight

(b) Identifying Characteristics of Organisms. Just as the characteristics of color, shape, size, and kind of edge were used in identifying the paper figures, so are these characteristics used in identifying living organisms. Additional characteristics are also used in identifying organisms, such as body temperature, method of breathing, outer covering, and mechanics of breathing.

Distribute to each group one of the organisms from the several possible pairs listed below. These pairs were selected because they show some resemblances. Other pairs could be selected that can be used equally well. Each organism should be numbered. Instruct each group to describe its specimen so that other pupils can recognize it. Collect the descriptions and duplicate them.

On the following day, distribute copies of the descriptions without the identifying numbers, to all pupils, and place the numbered organisms on tables. Have each pupil match the descriptions to the proper organisms. This gives practice in applying descriptions to organisms. If some descriptions fit both members of a pair, an excellent illustration is provided of the need for complete and accurate descriptions.

Organisms:

Ivy and philodendron
Cricket and cockroach
Housefly and honey bee
Grasshopper and katydid
Frog and toad
Earthworm and centipede
Salamander and lizard
Black oak and white oak
Silver maple and sugar maple
Butterfly and moth

A-22. Principles of Classification [23, 22, 20]

This activity illustrates the principle of classification by which organisms having similar characteristics are grouped together. These groups are divided into smaller groups having still more characteristics in common. The small groups are still further subdivided until the list of characteristics considered fits only a single kind of organism.

Divide the class into small groups and use the paper figures prepared for activity A-21(a). All the figures taken together constitute a single group having in common the characteristic of red and the other yellow. Have the groups further divided into smaller ones having similar characteristics. Pupils may use color, size, or shape or a combination of these as the common characteristics. Again, divide the groups until each has but a single figure.

The fact that several bases of classification are possible illustrates the fact that pigeonholes of classification are somewhat artificial and arbitrary, particularly with respect to the larger groupings.

One example of a completed classification might be:

Paper figures (Class)
  Red in color (Order)
    Diamond shapes (Family)
      Smooth edge (Genus)
        Large (species)
        Small (species)

    Circles
      Smooth edge
        Large
        Small

Rectangles
  Smooth edge
    Large
    Small
  Wavy edge
    Small

Yellow in color
  Diamond shapes
    Smooth edge
      Large
      Small

  Circles
    Smooth edge
      Large
      Small

  Rectangles
    Smooth edge
      Large
      Small
    Wavy edge
      Large
      Small

The grouping or classification of the paper figures can be related to the classification of organisms by characteristics. The names of the various ranks of grouping in biological classification have been included in parentheses above. If another set of figures were cut of tinfoil, another class of figures would result. These classes could be grouped together to form a phylum.

Students should be led to see from a study of the above classification that larger groups include smaller groups. Members of smaller groups have many characteristics in common, while larger groups are more diverse. However, all members of larger groups have certain characteristics in common.

A-23. Study of Protozoa [4, 6, 1]

The ameba is one of the simplest protozoa and the paramecium one of the most complex. Both of these forms are easily available for study and can either be collected locally or obtained from supply houses. Put some leaves, grass, and silt from the bottom of a pond, together with some of the pond water, in a jar. Note: Other species of protozoa will be in the culture.

With a dropper put a bit of the sediment from the bottom of the culture on a clean microscope slide, add a cover slip and examine under low power of the microscope. Paramecium tend to accumulate near the bottom of the culture, feeding on the bacteria and other small organisms in the debris. Amebas are apt to be on the surface of decaying leaves or grass in the culture.

A-24. Study of Algae [6, 4, 1]

Pleurococcus (also called protococcus) is one of the simplest algae cells, and spirogyra one of the most complex. The former commonly grows on the bark of trees and the latter in ponds. Both are easily obtained and make excellent material for individual microscope study to develop skill in the use of the microscope and to emphasize the characteristics of algae.

(a) Microscopic Study of Pleurococcus. On the shady side of many trees the bark has a greenish color near the base. Break off a chip of bark from such a tree and take it to the laboratory. Gently pick off some of the green material from the bark onto a microscope slide with a dissecting needle, being careful to get only the green material and none of the bark. Cover the materials taken from the bark with a few drops of water and place a slip on the slide to make a temporary wet mount. Examine under the low and high power of the microscope (see diagram).

Irregular shapes, masses, or colonies of the pleurococcus cells will be observed. Since the cells reproduce by fission (splitting in two) and have no method of locomotion, masses of the cells accumulate.

A large green chloroplast nearly filling the cell is the most obvious structure seen. The nucleus ordinarily cannot be seen, since it is located in the center of the chloroplast and is colorless. A thin colorless cell wall bounded by a thin black line can be seen to surround the cell.

Pleurococcus is a one-celled alga with a cell wall, cell membrane, nucleus, a vacuole, and cytoplasm with one large chloroplast in it. But the cell is so small that you may not have been able to distinguish all these parts under your microscope.

With these cell parts, this microscopic alga does all the things a spirogyra does to stay alive. It makes food and digests it. It excretes cell wastes. It carries on respiration. It is sensitive to and reacts to light and other things. There is motion within the cell. It reproduces by dividing, and each new cell grows to full size.

(b) Microscopic Study of Spirogyra. There are many filamentous algae to be found in ponds, not all of which are spirogyra. There are also several species of spirogyra, some containing two or more coiled chloroplasts. It is suggested that the one with a single chloroplast be used for study. If none can be collected locally, it may be obtained from supply houses.

Put a few strands of spirogyra, either living or preserved, on a microscope slide and make a temporary wet mount with water and a cover slip. The material can be handled more easily if it is cut into short lengths. Pick up a group of strands with tweezers and cut with sharp scissors.

Observe under low and high power of the microscope. A colorless cell wall is visible, and the coiled green chloroplast is prominent within the cell. The nucleus is seen as a dark gray sphere near the center of the cell, although it may not be visible in all cells because sometimes it is covered from view by a piece of the chloroplast. The cytoplasm is a very faint gray, and will require reduced light to be seen.

If the cover slip is removed and a few drops of iodine added to the material, the pyrenoid bodies or starch-storing areas of the chloroplast turn a deep black. If live material is used, it is best to expose it to a bright light for several hours before use so that there is an abundance of starch in the pyrenoid bodies.

A-25. Study of Mosses [2, 1, 4]

Bring several clumps of moss to school. Soak them overnight in water. With tweezers, separate out individual moss plants. Put them on white cards and have pupils study them under a magnifying glass. Determine leaves, stems, and root-like structures. Some specimens may have filaments growing upward with spore-producing cases at the top.

A-26. Study of Ferns [1, 2, 11]

Have pupils bring to school fronds of ferns, either from the wild or from house ferns. Look for brown bumps on the back of the fronds. These are spore-producing organs, called sori. If the spores are ripe, they will fall out when the frond is lightly tapped on a piece of white paper.

To grow fern spores, thoroughly wet a five-centimeter flower pot by soaking it in water for several hours. Invert it in a dish of water. Sprinkle the fern spores on the inverted bottom of the flower pot. Cover the pot with a glass jar to maintain a saturated atmosphere around the spores. Supplied by moisture from the pot, and in the saturated atmosphere, the spores will germinate and begin to grow in several weeks.

A-27. Spiders and Insects [8, 14, 2]

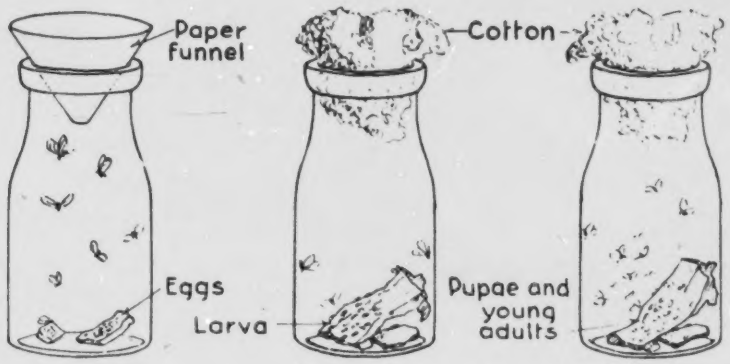
Look for spiders and their webs on grass and shrubs. Spiders are not insects since they have eight legs and two main body parts, while insects have six legs and three body parts. Look particularly for spiders with egg sacs attached. If any are captured, keep them in terrariums or insect jars and watch the young emerge.

A-28. Role of Insects [19, 21, 22]

(a) Although blowfly larvae normally feed on carrion they can be raised on dog biscuit. Get some kibbled dog biscuit and fill a liter jar with it to the depth of 5 centimeters. Cover the biscuit with water for two or three minutes and then drain. Add eggs or larvae to the jar and cap with fine wire mesh or cheese cloth. When the larvae are full grown, fill the jar with coarse sawdust in which they will pupate. Keep the adults in screened cages or jars. Feed them water, sugar, and moist dog biscuit.

Eggs of the blowfly can be collected by allowing meat or moistened dog biscuit to stand outdoors for several days. The adult female will lay several hundred eggs on the meat or moist dog biscuit. The eggs hatch in about 24 hours. Another way to raise blowflies is to place a piece of raw meat on a layer of moist sand in a liter jar. The insects will lay eggs in the meat and the larvae will feed on the meat and go into the sand to pupate. It takes a blowfly about a week or ten days to reach the pupal stage and about two weeks for the adults to emerge. In nature, pupation takes place below the carrion or slightly below the surface of the ground. The blowfly is another example of an insect with complete metamorphosis.

(b) Several generations of fruit flies may be raised with a minimum of attention. Prepare a suitable habitat by dropping a piece of ripe banana or a few grapes into a 250 milliliter beaker. Fit a paper funnel into the top of the bottle. Soon fruit flies will go to the fruit at the bottom of the bottle but will find it difficult to escape because of the paper funnel. In a short time flies will deposit eggs on the fruit. When six or more flies have entered the bottle, remove the paper funnel and plug the top with absorbent cotton. With this number of flies there should be some males and some females. Females can be distinguished from the males by their larger size. The female has a slightly broader abdomen than the male with small lines across the tip. The smaller male has a black-tipped abdomen. Larvae will emerge from the eggs in a couple of days and feed on the fruit for about a week and then pupate. A piece of crumpled paper toweling can be dropped into the bottle for the larvae to crawl on and pupate. After five days some of them will change to adults. The flies will mate a short time after emergence. A new bottle or habitat can be prepared and a third generation established. In this way the entire life cycle can be observed in a very short time.



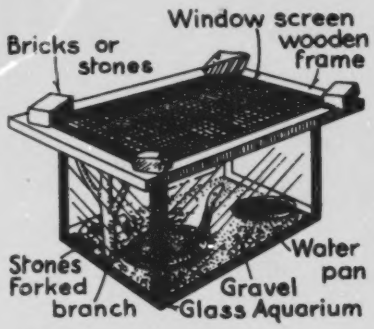
A-29. Amphibians [1]

Try to observe a toad or a frog which is eating insects. The tongue of these amphibians is attached at the front of the lower jaw and flips out rapidly to catch the insect so that it will be necessary to watch closely to see this action. Another way of observing the tongue is to dangle an earthworm or a small piece of lean meat or liver strung on a fine unknotted thread in front of the animal.

A-30. Characteristics of Reptiles [1]

A snake commonly seen in the spring is the garter snake. It is secretive and prolific, which may account for its survival so close to human habitations.

If a garter snake is found on the school grounds, have the pupils approach it quietly and slowly to observe it. When handling a snake, it is best to hold it with one hand securely but not too tightly just behind the head. Support the rest of the body with the other hand. When first held, the garter snake may emit a musky offensive smelling fluid from the glands near the tail. This is a protective device. This secretion is not harmful and can be washed off with soap and water.



If a particularly fat garter snake is brought in, keep it for several days or longer to see if it will give birth to living young, as the garter snake is viviparous. As many as 20 to 40 may be born at one time. Keep the garter snake in a reptile cage or in an aquarium with a screen cover, weighted down securely as shown in the diagram.

A-31. Bird Identification [1]

Bird study can be a part of every fieldtrip whether the trip is made for the special purpose of observing birds or for some other purpose. Knowing something of the behavior and outstanding characteristics of different kinds of birds makes them much easier to identify in the field. The following brief outline will be helpful in learning to recognize most of our common birds.

1 Hummingbirds are the smallest and swiftest of birds and have iridescent plumage. They buzz about flowers and extract nectar and tiny insects with their long, needle-shaped bills.

2 Woodpeckers have long, strong bills and climb up and down trunks of trees. They use their tails to brace themselves and they tap the bark vigorously.

3 Flycatchers sit erect with drooping, teetering tails, watching alertly for insect prey. They catch insects in mid-air and then return to their perch.

4 Larks are birds of sparrow size that walk rather than hop over the ground as they feed on weed seeds. Feathers above eye are erectile and give the appearance of horns.

5 Swallows have long, pointed wings and skim through the air in graceful and long sustained flights. They often perch on telephone wires.

6 Crows, ravens, and jays are good-sized birds with raucous calls and bold behavior. They usually inhabit open fields or wooded areas.

7 Titmice and chicadees are small, noisy, active, restless birds that feed largely in foliage or on inner limbs. They have fluffy, grayish plumage, and short straight bills with which they often hammer seeds with woodpeckerlike blows while holding them with their feet.

8 Nuthatches are smaller than woodpeckers and have much the same habit of climbing up and down tree trunks. They climb about with a wig wagging motion, often descending head downward.

9 Creepers, as the name signifies, creep upward on the trunks of trees and the larger limbs as they search for insects in the crevices of the bark. They have long curved bills and sharp pointed tail feathers.

10 Wrens, with tails erect, slip mouselike about brush heaps, crevices, and bushes.

11 Thrashers and mockingbirds have long curved bills and long tails. They inhabit bushy areas and orchards. They are noisy and often imitate the sounds made by other birds.

12 Thrushes, with the exception of the robin and bluebird, are very plainly dressed and have spotted breasts. They run about on the ground and often stop suddenly in a listening attitude.

13 Kinglets are tiny chubby birds with large eyes. They move restlessly about in foliage.

14 Waxwings are conspicuous because of a crested head and yellow-tipped tail. They are usually seen in large flocks feeding on berries in trees or bushes.

15 Shrikes are usually solitary and choose conspicuous perches. In silhouette, a flat-topped head, short neck and hooked bill are evident.

16 Vireos are chubby, large-eyed birds, almost the color of foliage. They are at home on the boughs of trees and sing freely as they glide in and out among the leaves to feed.

17 Warblers are small, tireless, gaily-colored explorers of the twigs of trees and bushes. A few exhibit flycatcher-like habits.

18 Blackbirds and orioles have bright plumage and usually inhabit open fields. The sexes differ in coloration. Winter flocking is the rule.

19 Tanagers are remarkable for the brilliant plumage of the males. They are birds of the coniferous forests during the summer, but during migration visit fruit orchards.

20 Sparrows and finches have stout seed-cracking bills. They feed on or near the ground and are usually fine songsters.

A-32. Bird Study [2, 1, 14]

(a) The following outline may be used as a basis for the study of individual birds and also for suggestions of points to be observed on fieldtrips.

OUTLINE FOR THE STUDY OF BIRDS

Name of bird

Length, as compared with English sparrow, robin, or crow

Shape
- Body—long and slender; short and stout
- Bill—Long and slender; long and heavy; short and stout; hooked; curved; short and wide at base
- Tail—Long or short; forked; rounded or square at end; notched
- Wings—long and slender; short and rounded
- Legs—Long or short

Color
- General colors—Bright or dull
- Special markings
  - Top of head—Stripes, spots or plain
  - Back—Streaked or plain
  - Breast—Plain, speckled, streaked or spotted
  - Throat—Plain or streaked
  - Wings—Bars or patches
- Tail—Borders, bands or patches

Where seen
- About houses, gardens, orchards, fields, canyons, on bushy hillsides, deserts or about lakes and rivers
- In trees (trunk, branches, or among leaves), on the ground, in the air, or on the water

When seen
- All the year (residents)
- In summer or winter only (visitants)
- During migration (migrants or transients)
- Date when seen

Movements
- Deliberate or nervous; walks, hops, forks tail, flits wing, bobs body or head, teeters, raises and lowers crest

Habits
- Quiet, active, noisy, or silent
- Found singly, in pairs, or in flocks

(b) A trip to a natural science museum is a very valuable experience. If it is not possible to visit a museum, find out if a school collection of mounted birds is available. Often by inquiring among the pupils or members of the local rod and gun club it is possible to borrow mounted birds and similar exhibits for study.

A-33. Characteristics of Guppies [19, 20, 21]

Guppies are viviparous fish that are easily bred if the water in an aquarium can be kept at an average temperature of from 21.1°C to 23.3°C. An aquarium heater which maintains a constant temperature may be necessary.

Guppies can be bought reasonably at almost any pet shop, or some pupil may bring some from his home aquarium. Keep a pair in an aquarium stocked with thick, bushy water plants, particularly on the side toward the light. The male is the smaller and more brightly colored. The female is much plumper, especially when she is carrying young.

Guppies are cannibalistic, and if the vegetation of the aquarium does not protect the young from the adults, remove them to another aquarium. Feed adults on prepared fish food, tiny bits of meat, earthworms and small insects. Feed the young on finely powdered fish food.

A-34. Observing Habits of Young Mice [14, 17, 19]

If arrangements for some care over weekends can be made, it will be valuable and interesting to raise a litter of young mice.

Select a pair of young, healthy white mice as parents. White mice have been bred in captivity for many generations and do much better then wild varieties. They are easily obtainable from pet shops and biological supply houses.

Feed the mice on broken dog biscuit, bread and some green food as lettuce, cabbage, celery or apple. To provide water, stick a medicine dropper of water through the mesh into the cage.

Keep the mice together for a time to allow them to mate and then separate them. Give the female shredded paper and some cotton for nest making. The period of gestation is about 21 days. The young are weaned in about three weeks. Refrain from handling the newborn young. Coax the female out of the nest and then look into the nest through the top of the cage to see the young. Let the pupils observe the young daily and how the mother cares for them. Have pupils keep a day-by-day record of the development of the young.

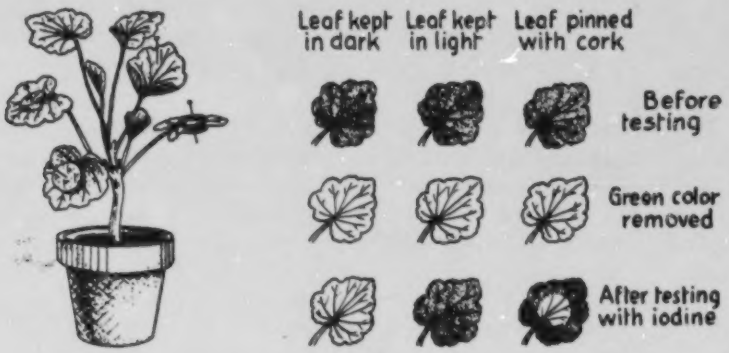
A-35. How Plants and Algae Make Food [23, 22, 21]

Plan to use 10 or 15 minutes of a class period to describe and begin the following experiment which can be completed the next day.

Before beginning the experiment, review the observations made in connection with the reactions of plants to light. Suggest that there is reason to believe that these reactions may have something to do with the way green

plants obtain their food. Solicit suggestions from pupils as to possible ways to test this hypothesis, then plan an experiment involving the testing of leaves for starch under different conditions of exposure to light.

If two potted geranium plants are available, pupils can usually be led to propose setting one away in a dark place and leaving the other in the light until the following day.



Now describe a modification or check on this experiment. Pin several pairs of flat corks (or ends cut from ordinary corks) over some of the leaves of one geranium plant. Stick pins through the other leaves to be tested, too. Point out that the portion of the leaves between the corks cannot obtain light and try to develop curiosity as to what may happen.

Complete the experiment by removing the leaves containing the corks. Boil the leaves several minutes in water and soak them in hot alcohol until all the green coloring matter is removed. Place the leaves in dilute iodine solution and note the portions where starch was or was not present. Leaves are covered with corks and leaves from the plant kept in darkness should, of course, also be tested. Results can be summarized as indicated in the diagram.

A-36. Water is Needed for Photosynthesis [17, 14, 1]

Observe the root hairs of radish seedlings with a hand lens. Radish seedlings with a luxurious growth of root hairs can be grown in 2 or 3 days in the following way. First soak some radish seeds over night. Then line a drinking glass with a paper towel and wet the paper so that it sticks to the glass. Place the soaked seeds between the wet towel and the glass about 2 centimeters below the rim. Pour about 3 centimeters of water in the glass to keep the paper moist.

A-37. Water for Photosynthesis Obtained Through Roots [8, 9, 10]

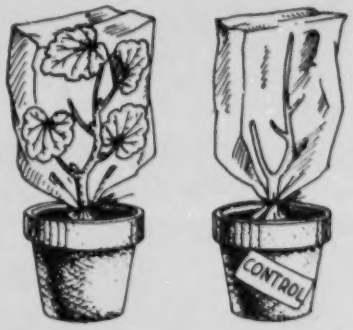
The fact that water for photosynthesis in the leaves of a plant enters the plant through the roots and reaches the leaves by way of the stem can be illustrated with a young bean or pea plant. Grow the plant in nutrient solution in sand. When it is 15 to 20 centimeters tall, tip the pot to remove the plant with as little root damage as possible. Carefully wash the sand from the roots under running water and put the roots in a beaker containing safranin stain or red vegetable dye.

When the red color can be seen in the veins of the leaves, remove the plant and cut across sections of the roots, stem, and leaves. The fact that there are specialized conducting channels through all structures will be shown by spots of red in the cross sections. The red color in the leaves will indicate the source of the water that reaches them.

A-38. Transport in Leaves [16, 9, 4]

(a) Rub a leaf of a tender-leaf plant such as the wandering Jew between the fingers so as to loosen the tissues. Peel off a thin piece of epidermis from the bottom of the leaf. Place this bit carefully on a microscope slide with a drop of water and a cover glass. The little mouth-shaped structures are openings which admit air to the leaf.

(b) Place a plastic or cellophane bag, such as is used for food storage, over a potted house plant. Tie the mouth of the bag tightly around the stem of the plant. As a control put another bag of the same kind over a dead branch set in a similar flower pot. Set both in sunlight and note which bag collects more water. The escape of water from leaves is called transpiration. Some of this excess water given off may already have served a useful purpose in carrying dissolved minerals into the plant. Plants also need a continuous supply of water coming from the roots to keep them from drying out.



A-39. Separation of Chlorophyll Pigments [7, 5, 8]

Chlorophyll is actually a complex mixture of a number of different compounds. These can be separated and analyzed in a variety of ways. Because the compounds in chlorophyll are of different color, they can be separated by the method of chromatography. The chalk column method is simple and requires but a small amount of material.

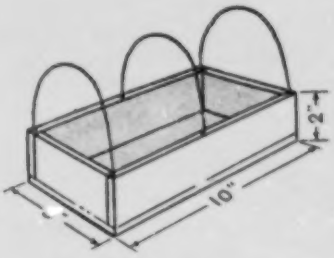
Soak about 40 milliliters of chopped, frozen spinach overnight in 250 milliliters of a mixture of equal parts of acetone and rubbing alcohol. Keep the mixture in a stoppered flask during the time that it is soaking. The next day, decant the liquid that will contain in dissolved form the mixture of chlorophyll pigments.

Pour some of the liquid into a small dish such as a petri dish. Stand a piece of chalk upright in the mixture of liquids ("soft" chalk will give somewhat faster results) and cover with a beaker to provide a saturated atmosphere around the chalk. Leave the chalk in the liquid until it is wet to the top.

Remove the piece of chalk and with a pencil mark the limit of the solvent and the colors and positions of the various pigment bands. This is necessary because the solvent evaporates rapidly and the pigments often fade or change color (see diagram).

A-40. Most Effective Colored Light for Photosynthesis [19, 21, 22]

To determine what color of light is most effective for photosynthesis, make five trays of wood about 12 centimeters wide and 25 centimeters long, as shown in the diagram. Drill three holes into each side of each tray; insert the ends of the arches made of coathanger wire as shown.



Plant an equal number of seeds in the trays and fasten colored cellophane over the wire arches and down the side of each tray. It is suggested that red, blue, green, yellow, and colorless cellophane be used. The material should be fastened so that it can be slid off each day for measuring the growth of the seedlings and for watering.

A-41. Carbon Dioxide Needed for Photosynthesis in Land Plants [17, 16, 11]

Using a geranium plant that has been in the dark for a day or two so that there is no starch in the leaves, cover a leaf, still attached to the plant, with waterproof cellophane. Fold the cellophane so that it covers both top and bottom of the leaf and seal all edges with cellulose tape. This will prevent any atmospheric gases from entering the leaf.

Expose the plant to bright sunlight for a day or two, or to the light of a 200-watt bulb 1 meter away from the plant for 24 hours. Be sure that the plant is well watered. This will provide the experimental leaf with all the necessities for phososynthesis except atmospheric carbon dioxide.

After exposure to light, remove the covered leaf and a similar uncovered leaf from the same plant. Remove the chlorophyll by boiling in alcohol, and test for the presence of starch. The covered leaf would not be expected to have starch present, while the control (uncovered leaf) should show a strongly positive test for starch.

A-42. Oxygen - A Waste Product of Photosynthesis [10, 9, 8]

Make use of the formulas CO_2 and H_2O in developing an elementary understanding of what is believed to occur when plants manufacture carbohydrates.

Point out that carbohydrates are made up of the element carbon plus hydrogen and oxygen. The hydrogen and oxygen are always in the same proportion as they are in water. Thus, it is apparent that there will be some oxygen left over (byproduct) when CO_2 combines with H_2O in the formation of a carbohydrate.

The release of oxygen into the air cannot of course be observed but it can easily be observed from certain water plants such as the common aquarium plant *Elodea*.

Cut two or more tips of *Elodea* about 5 centimeters long and place them in a beaker of water in bright sunlight. Tiny bubbles which are mostly oxygen can be seen issuing from the cut stems.

Hold a card in front of the beaker containing the *Elodea* tips so as to cut off the light. Bubbles no longer are seen. Remove the card and they begin again.

A-43. Green Plants Need Inorganic Materials [17, 12, 14]

Green plants need certain mineral salts in order to produce protoplasm and grow. Compounds of nitrogen, phosphorus, and potassium are the ones needed in largest quantities. These chemical compounds are dissolved in ground water and are absorbed through the root system.

Grow a number of seedlings of oat, wheat, radish, or mustard in two containers of sand. Water only with distilled or demineralized water. In a short time the nutrient material stored in the seed will be exhausted.

As soon as the plants have developed green leaves, water one group with a liquid fertilizer, of the type which can be obtained at garden supply stores. Continue watering the other (control) group with distilled or demineralized water. A difference in growth between the two groups should become apparent within a week or 10 days.

A-44. Fungi Are Dependent Upon Green Plants for Food [16, 10, 9]

To show that fungi are dependent on green plants directly or indirectly for food, sprinkle some mold on wet, washed sand in a jar. Cover the jar and set it aside for a week.

Wet a piece of bread and sprinkle some mold on it. Put the bread in a jar and cover it to retain a moist atmosphere. Set this jar aside with the other one for a week.

The bread, made from wheat, a green plant, will provide needed nutrients for the growth of the mold, while the sand will not. It is important to wash the sand before use to be sure there is no organic matter present which might provide nutrients for the mold.

A-45. Test for Starches [8, 6, 10]

Mix a little cornstarch into one glass of water and set another glass of water beside it for comparison. Place a few drops of iodine solution in each glass. The blue-black color is a common test for starch. Place a drop of iodine on a piece of bread and on a cracker. Also test table sugar, baking soda, an onion, and other starch-free foods. Suggest that pupils test some foods at home such as macaroni and boiled rice. Compile a list of foods that contain starch.

A-46. Test for Fats [11, 8, 6]

An interesting test for fats and oils actually recovers them. Pulverize a food sample such as a few nut meats and cover it with carbon tetrachloride. The carbon tetrachloride will dissolve most of the fat or oil present. After removing the nut meats, pour the solution into a glass evaporating dish and allow the solvent to evaporate, leaving the fat or oil.

A-47. Tests for Proteins [6, 4, 2]

(a) To a little egg white in a test tube add an equal amount of water and shake thoroughly. Add an equal amount of 10 percent sodium hydroxide solution and, after mixing, add two or three drops of a 3 percent copper sulfate solution. The presence of proteoses and peptones from proteins is indicated by a violet or pink-violet color. Repeat the procedure using a variety of foods.

As an alternative procedure, the biuret reagent can be prepared in advance by mixing 2.5 cc of a 3 percent copper sulfate solution with 100 cc of a 10 percent sodium hydroxide solution and dispensing from a dropping bottle. The reagent is somewhat unstable and usually deteriorates by precipitation in about 24 hours.

(b) An older and better known test for the presence of proteins involves the use of concentrated nitric acid and, in the interest of safety, should be carried out as a demonstration by the teacher.

To about a half teaspoonful of the food in a pyrex test tube add an equal amount of concentrated nitric acid and bring to a boil over the flame of a Bunsen burner. Pour off the acid, rinse with water, and neutralize by covering with ammonium hydroxide. An orange color, deepening on the addition of the hydroxide, indicates the presence of protein.

This test is useless with liquid sources of protein such as milk and those with a yellow or orange color such as cheese.

A-48. Tests for Minerals [14, 6, 2]

(a) A mineral needed for the proper operation of the thyroid gland is iodine. Iodine is found in various natural foods but if the supply is not adequate, the deficiency may be made up by using iodized salt. The presence of iodine in iodized salt can be shown by a simple test. Take one-fourth of a test tube of dry cornstarch and add an equal amount of dry iodized salt.

Wet the salt by pouring in a little bromine water or chlorine water. Note the dark blue-black color near the dividing line of salt and starch. This shows that iodine is present. Note that the reverse of this test is used to identify starch. Try using bag salt which is not iodized and note the absence of the blue-black color.

(b) Certain foods such as cabbage, red meats, and liver contain iron. To show the presence of iron place a small amount of liver in a beaker with enough dilute hydrochloric acid to cover the bottom of the beaker. Add an equal quantity of distilled water. Boil for two or three minutes. When cool, mix enough dilute nitric acid to raise the level 0.3 centimeter. Filter the liquid and divide the filtrate into two portions. To one portion add a small amount of potassium thiocyanate (KCNS). A pink curd or precipitate denotes the presence of iron. As a check, a small amount of potassium ferrocyanide $K_4Fe(CN)_6$ may be added to the other portion. A blue-colored precipitate (curd) should now be obtained if iron is present.

A-49. Vitamin C Content of Foods [12, 5, 3]

Prepare the test reagent by dissolving 1 gm of 2-6 dichloroindophenol sodium salt in 1 liter of distilled water. The reagent is unstable at room temperature and after being prepared should be kept in a refrigerator when not in use.

Put 1 cc of the 0.01 percent vitamin solution in a test tube. You now have exactly 1 milligram of vitamin C in the tube. Add the reagent, which is blue, drop by drop. The first drops will turn colorless in the vitamin C. Continue to add the reagent, shaking after each drop, until a faint blue color persists. The number of drops required represents the number of drops required to neutralize 1 milligram of vitamin C.

Repeat the procedure using orange, grape, and other juices both fresh and canned. The amount of vitamin C contained in 1 cc of the food samples can be determined by simple proportion, using the information gained from neutralizing the vitamin C standard.

Foods such as raw onions, raw potatoes, and green peppers can also be tested. Thoroughly macerate the food in water and use the water for testing, since vitamin C is soluble in water.

Acid foods will produce a pink color when the reagent is first added. This is not the end point. A faint blue color must persist.

A-50. Need for Vitamin D [15, 12, 19]

Use four young rats or mice, 15 to 30 days old, for this experiment. Keep the animals in separate cages, or two in each of the two cages.

Feed two of the animals the Steenbeck diet, which consists of:

Yellow corn meal	76 percent
Wheat gluten flour	20 percent
Calcium carbonate.	3 percent
Sodium chloride.	1 percent

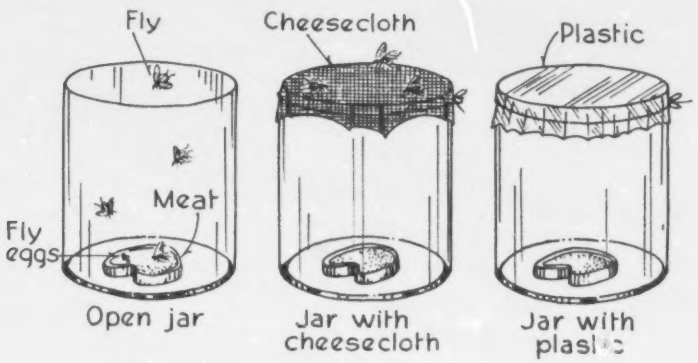
The other two animals are fed the same diet, to which viosterol has been added as a source of vitamin D in the amount of 20 drops per 1,000 gm of diet.

A plentiful supply of diet and water should be available to all animals at all times. The animals must be kept shaded so that there is no opportunity for them to synthesize vitamin D under the influence of light.

Weigh all animals daily and graph their rates of growth. Observe gait and posture and make records. When rickets appears in the experimental group in about 3 or 4 weeks, add viosterol to their diet and observe for signs of recovery.

A-51. All Living Things Come From Living Things [23, 22, 18]

For thousands of years it was believed that certain forms of living things came from nonliving matter. This theory of spontaneous generation was so firmly fixed in the minds of men that many classic experiments and three centuries of controversy were required to finally disprove it to the satisfaction of all. Some of these classic experiments are relatively easy to duplicate. Redi's experiment follows.



Place pieces of raw meat in each of three jars. Leave one uncovered, cover one with cheesecloth and the third with clear plastic (see diagram). Set the jars in the open where flies can be attracted by the odor of the meat. This, of course, must be done during a season when flies are active out-of-doors.

In a few days the eggs of flies will be found on the meat of the uncovered jar, on the cheesecloth of the second jar, and there will be no trace of flies around the jar from which the odor could not escape. Pupils may enjoy the short, readable account of this classic research in Redi's own words to be found in *The Autobiography of Science* edited by Harlow Shapley.

A-52. Budding in Yeast [6, 4, 1]

Budding is similar to fission in that the nucleus of the cell divides into two equal parts. However, budding differs in that the cytoplasm produces a small daughter cell, called a bud, which gradually enlarges to produce a mature cell. It may remain attached to the parent cell, and itself produce a bud. Thus, in observing a culture of actively growing yeast cells, pupils may see single cells, and clumps of cells frequently appearing as chains.

Crumble about a quarter of a yeast cake or a quarter package of dry yeast into some 10 percent molasses solution in a flask. Plug the flask and set it in a warm place overnight. The next day put a drop of the yeast-molasses mixture in the center of a clean microscope slide. Spread the drop with a toothpick, so that it covers an area about the size of a dime.

After the material on the microscope slide has dried in air, pass the slide, yeast side up, through the flame of a Bunsen burner 3 or 4 times to fix the yeast cells to the slide. Lay the slide across the top of a beaker and cover the yeast cells with crystal violet stain. After the stain has been on the slide for a minute, tip the slide to pour the excess stain into the beaker. Rinse the slide under gently running tapwater until no more color washes off. Examine under the low and high power of the microscope.

The warmth and abundance of food should produce a number of buds on the yeast cells. If dried yeast is used, better results may be obtained after growth has progressed 48 hours.

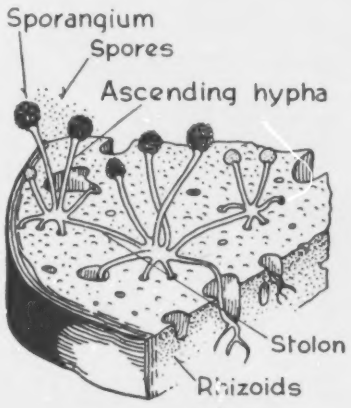
A-53. Molds Reproduce by Means of Spores [6, 4, 1]

While yeasts reproduce by means of spores under certain conditions, this is difficult to demonstrate. It is much easier to demonstrate the formation of spores by molds.

Sprinkle some dust on a half-slice of thoroughly dampened bread and put it in a pint canning jar. Screw the lid on the canning jar to provide a moist atmosphere and set it aside in a warm place for several days. As soon as mold appears on the bread, look for the appearance of black spots. These are sporangia, or spore cases.

With tweezers, put a bit of the mold with black spots on the center of a clean microscope slide and spread it out with a drop of water. Place a cover slip on the preparation and examine it under the low and high power of the microscope.

Large, balloonlike structures will be observed in some cases. These are the sporangia, containing spores. In some cases, the sporangia will have burst, revealing only the black spots which are the spores (see diagram).



A-54. Regeneration in Planaria [16, 10, 9]

Some plants and animals have the ability to reproduce lost parts of the body. When the lost part of the body has the ability to regenerate the body as well, this constitutes a form of reproduction. This is the case with planaria, hydra, starfish, and other forms. This process is most easily demonstrated with planaria.

Planaria can be collected in many ponds or streams. They may also be purchased from most supply houses. The worms can be kept in the laboratory in a pan about half full of water. They should be fed about once a week by placing small pieces of fresh beef liver in the pan. In several hours they will have finished feeding, at which time the liver should be removed and the water changed.

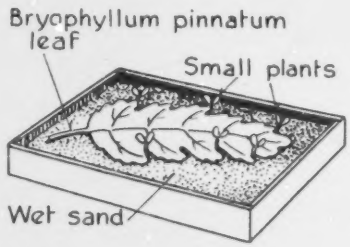
Put individual planaria in individual Syracuse dishes with a little water. With a sharp razor blade cut some worms in half and some in thirds. Make some of the cuts straight across and some diagonally. Cover the dishes by stacking them, putting an empty dish on the top.

Inspect them daily. Some regeneration should be evident within 48 hours. The back half should develop a new front half, and the front half a new back half. The middle third of those cut in thirds should develop new anterior and posterior ends. This is true reproduction, since in time one worm becomes two or three, depending on how the cuts have been made.

A-55. Vegetative Propagation by Leaves [16, 10, 9]

Some plants are capable of regenerating stems and roots from a single leaf or part of a leaf.

(a) Bryophyllum Leaf. The separation of a bryophyllum leaf from the parent plant apparently upsets its metabolism and stimulates the production of a hormone.



Place a detached leaf on wet sand or a wet cellulose sponge in a dish. Keep the sand or sponge moist and in a week or so tiny plants will appear at intervals in the notches of the leaf. The leaves are easily broken off and this is the natural method of reproduction of this plant in Florida, where it grows as a weed. In a short time the tiny plants can be detached from the parent leaf which has been supplying food material and planted in soil, where they will grow independently (see diagram).

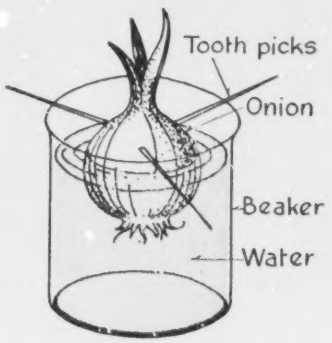
(b) Begonia Leaf. Insert the petiole of a leaf into moist sand or soil. Keep moist and watch for the appearance of rooting and shoots. This same procedure can be used with African violet leaves.

A-56. Vegetative Propagation by Stems 16, 10, 9]

A number of stems are specialized for the vegetative propagation of the plant.

(a) Propagation from Bulbs. A bulb is a compact mass of fleshy leaves surrounding a short, small stem. Small lateral buds develop at the base of the stem, producing bulblets which grow into new plants.

Onion, lily, narcissus, hyacinth, are common examples of bulbs. All of these may be grown in the laboratory, either in soil or partially submerged in wet sand or pebbles. Onions will grow well partially submerged in water (see diagram).



(b) Propagation from Corms. A corm is a short, stubby solid stem with a few leaf scales on the outside. Lateral buds at the base of the stem form cormels, in the same manner that bulblets are formed.

Tulip, crocus and gladiolus are common examples of corms. Tulip and crocus corms should be lightly covered with loam, well watered and kept in a refrigerator for 3 or 4 weeks in order to break their dormant period. They can then be planted in soil in the usual way for winter growth. These, like many other spring plants, need a preliminary period of cold before they grow actively.

(c) Rootstocks or Rhizomes. Rootstocks or rhizomes are underground stems that grow out from the parent plant. At intervals, nodes form from which roots grow downward and stems upward. Sansevieria or snake plant can easily be grown in the laboratory to illustrate this.

Other plants that reproduce by means of rootstocks include calla lilies, a large number of ferns including the popular Boston fern, Johnson grass, and Bermuda grass.

(d) Runners or Stolons. Runners or stolons are trailing stems that project horizontally above ground from the plant. At their ends, roots grow downward and stems upward. This results in a row of plants connected by runners. The strawberry geranium and the spider plant can be grown in pots in the laboratory to illustrate reproduction by means of runners. Some common aquarium plants, such as eel grass (Vallisneria) and Amazon sword plant also illustrate this type of reproduction. Strawberry plants also produce numerous runners. Request a pupil to bring one to class.

(e) Tubers. Tubers are thickened underground stems in which there is a good deal of food storage, largely in the form of starch. The new plants grow from the "eyes" of the tuber, which are really lateral buds of the stem. Potatoes and dahlias are common examples of tubers. They can be grown in the laboratory quite easily in wet sand.

An interesting experiment can be conducted by cutting a potato into six parts, three with eyes and three without eyes, and planting them in wet sand. The parts with eyes will produce growth, while those without eyes will not.

(f) Layering. With some plants having trailing stems, roots and a new plant will grow where the tip of the stem touches the ground. This is the case with rambler type roses, raspberries, and certain blackberries. This may be done purposely to propagate these forms, and the young plant later separated from the parent.

English ivy and Philodendron are easily grown in the laboratory to illustrate this type of reproduction.

A-57. Vegetative Propagation from Roots [16, 10, 9]

The roots of sweet potato, carrot, beet, and turnip contain much stored food and will produce a profusion of foliage under proper conditions.

Cut the end off a sweet potato and set it, cut end down, in a jar of water. Keep the lower end covered with water. In a week to 10 days buds producing stems and leaves will appear.

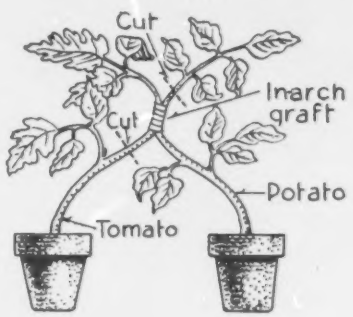
Remove the old leaves from a carrot, beet, or turnip and cut off the top inch of the root. Place this top portion in a dish of water with a little sand to hold the root in position.

An interesting laboratory exhibit may be prepared from these materials.

A-58. Artificial Vegetative Propagation [22, 19, 14]

The types of vegetative propagation described in activity A-56 all occur naturally without any help from man. Sometimes it is desirable to propagate other plants vegetatively in order to get plants exactly like the parent type and to get plants more quickly than growing them from seed.

(a) Stem Cuttings. The stems of a number of plants, if cut from the parent plant and put in water or wet sand or soil will grow new roots, producing a new plant. Geranium, begonia, coleus, and ivy are all excellent to illustrate this method of propagation.



To prepare a cutting, cut the stem diagonally with a sharp knife directly below a node, leaving about three nodes in the cutting. Insert it about an inch and a half deep in wet sand or vermiculite. Roots will form in about 3 or 4 weeks, when the plant should be transferred to a pot of soil. Rooting can be hastened by dipping the cut end of the stem in root-forming hormone (available in all plant nurseries) before putting it in the wet sand.

(b) Grafting. Some plants will not form roots from stem cuttings. In this case, it is necessary to graft the stem cutting, or plant it in the stem of a similar or closely related plant. This is the common way of reproducing most fruit trees and many types of roses.

An illustration of grafting that produces quick results in the laboratory can be done by joining a potato and a tomato plant. This is known as an in-arch graft, and somewhat different from the simple stem graft.

Grow a potato plant from a piece of tuber and a tomato plant in two pots side by side, or together in a large pot. When the two plants are each about 25 centimeters tall, bring the two stems together. Where they will touch, shave the outer portion of each stem for a distance of about 5 centimeters until several vascular bundles of each stem are exposed. Bring the cut surfaces together, as shown in the diagram on page 68 and carefully tie them together with soft cord or raffia. Seal with paraffin or grafting wax.

The two plants should grow together in about 4 weeks. If so, cut off the tomato stem below the graft and the potato stem about the graft. You now have a plant with potato roots and the leaves and stems of a tomato. If the plant can be kept growing, it is possible to produce potatoes below the ground and tomatoes above the ground on the same plant. This graft is possible because the potato and tomato plants are closely related.

A-59. Study of Flower Parts [1, 4, 6]

Most textbooks contain good pictures and descriptions of the essential parts of a flower. Gladioli, tulips, and other members of the lily family are excellent for student study since they conform to the "typical" floral pattern. Twigs of apple, pear, and other fruit trees can be forced in the laboratory in the winter and early spring; while not "typical," their flowers are good for study.

Examine the floral envelope, which consists of sepals and petals. The outer whorl of flower parts consists of sepals, which together make up the calyx. Inside this is a whorl of petals, which together make up the corolla. In both the gladiolus and tulip, the sepals and petals are alike in size, shape, and color. The main function of the floral envelope is to attract insects which aid in pollination.

Carefully remove the parts of the floral envelope. The essential organs (those necessary for reproduction) are the stamens and pistil. The pistil is in the center of the flower, and is divided into three parts at its tip. (In a few tulips, the tip of the pistil will be found to be divided into four parts.) Surrounding the pistil is a ring or whorl of stamens.

Each stamen consists of an enlarged upper part which produces pollen, called the anther. This is supported by a thin stalk called the filament.

The pistil consists of an enlarged base containing the ovules which will develop into seeds. This is the ovary. The upper part, or stigma, which receives the pollen, is supported by a thin style. In the tulip, the style is very short.

With a razor blade, make a thin slice of the ovary crosswise and examine it under a tripod magnifier. It will be seen to consist of three compartments, each containing a number of ovules. These ovules will develop into seeds. It should be emphasized that before the ovules can develop into seeds, the processes of pollination and fertilization must take place. Involved in these processes are reduction division and the union of a male and female nucleus. The details of what takes place in the flower following pollination can be found in most high school and college texts.

A-60. Study of Flower Types [8, 14, 1]

(a) In the study of flowers, pupils will soon discover kinds that seem to have no pistils and stamens. The common dandelion is an example.

Pick some dandelion blossoms and pull them apart. Each blossom is made up of many tiny flowers. With the aid of a hand lens, the pistils and stamens in these individual flowers can be seen. Flowers of this kind are called compound flowers.

Find other examples of compound flowers and examine them with a hand lens.

(b) The number of individual flowers in a dandelion blossom can be found quite accurately by counting the matured seeds on a seed head. Each seed develops from a separate flower.

(c) Collect a bouquet of pussy willows for the classroom. The kind usually gathered have staminate blossoms. Try to find plants that bear yellowish pistillate blossoms and bring in some of these also. Use these and other examples in developing the understanding that the sexes are separate in many plants.

Junipers, yews, mistletoe, American holly, willows, and poplars are examples of plants in which pistillate flowers and staminate flowers are borne on separate plants.

A-61. Growing Pollen Tubes [10, 9, 4]

Prepare a small amount of a 10 percent sucrose solution. Then ring a depression microscope slide with vaseline. This can be done by dipping the mouth of the test tube, slightly larger around than the depression in the slide, into vaseline and pressing it on the slide.

Into a drop of the sugar solution in the center of a clean cover slip, shake some pollen from a mature stamen of a mature flower. Invert the cover slip over the depression and gently press it down against the vaseline ring. You now have a hanging drop preparation that is protected against drying out. Set the slide in a warm place for a day or two.

Examine under the low power of the microscope and look for germinating pollen grains with tubes. It is often possible, under subdued light and high power, to see three nuclei in the tubes — one tube nucleus and the two reproductive nuclei.

A-62. Pollination by Bees [14, 1, 4]

(a) Observe the gathering of nectar by bees and other insects. A plant that is being visited by bees makes a good destination for a short field trip. Try to locate such plants on or near the school grounds.

Observe the shapes of the flowers that are visited by bees. Note the position of the pistils and stamens in relation to the nectar glands. In many flowers it is impossible for an insect to obtain nectar without rubbing off some of the pollen and carrying it to other flowers where it may touch the pistil.

(b) Catch a bee and place it in the killing jar. Then observe it closely with the aid of a hand lens. Notice the hairs to which pollen may cling while the bee is feeding. Find the pollen baskets on the legs. Note how the mouth, legs and other parts are fitted for obtaining nectar from flowers. Locate the stinger.

Demonstrate the following method of catching stinging insects safely. Move a wide mouth glass jar over the insect and bring a piece of cardboard upward under it. With the cardboard still in place set the jar, mouth downward, on the killing jar and withdraw the card.

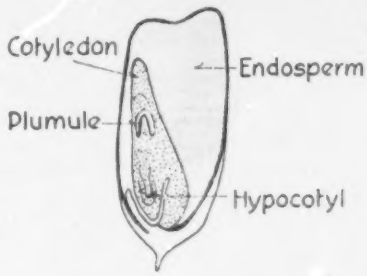
Wasps and other insects can often be captured alive indoors by setting a glass jar over them and slipping a card under the mouth of the jar.

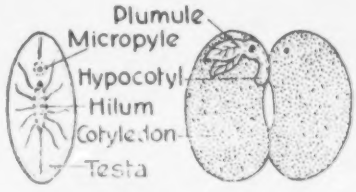
A-63. A Study of Seeds [1, 6, 4]

Corn seeds and lima beans are excellent examples of monocot and dicot seeds, respectively. They can easily be studied individually by students with the aid of a hand lens or tripod magnifier.

The day prior to their use, sufficient seeds to provide at least one for each student should be put to soak in water. Have 5 centimeters of water covering the seeds in a beaker to allow for that absorbed by the seeds.

(a) Corn Seed. An ear of corn is actually a single receptacle with a number of ovaries attached to it. Each kernel of corn is an ovary containing a single seed. The silk is the style of the pistil, and the tip of the silk the stigma.





Examine a single soaked kernel of corn. At the end opposite its attachment to the cob will be seen a little projection, which is the silk scar.

On one side of the kernel is a slight bulge, which is caused by the embryo plant within the seed.

Stand the kernel of corn vertically on a table, silk scar uppermost, and cut it into a right and left half, using a sharp knife or razor blade. Add a drop of iodine solution to the cut surface of the corn kernel. The larger part which stains black, indicating the presence of starch, is the endosperm. The embryo, consisting of hypocotyl (which becomes the root of the plant) and epicotyl (which will produce the stem and leaves) with its attached cotyledon, do not contain starch. These structures can easily be made out with the aid of a tripod magnifier and comparison with the diagram.

(b) Bean Seed. Examine the outside of a soaked lima bean seed. The hilum can be seen as a scar on one edge of the bean. This marks the place where it was attached to the pod. The micropyle is a very small hole near one end of the hilum. This marks the spot where the pollen tube entered the ovule, and is where water enters when the seed germinates.

Carefully remove the thick seed coat, or testa. When the testa is removed, the two halves are visible. These are the two cotyledons that are characteristic of dicotyledonous seeds. They contain the food that will be used by the embryo plant in its first growth.

There is no endosperm in dicot seeds. It has been absorbed in the development of the ovule into a seed and its food material incorporated into the cotyledons.

Separation of the cotyledons will uncover two tiny leaves and a stem, the epicotyl. The large structure attached to the epicotyl is the hypocotyl. This will form the root system of the new plant. Together, the epicotyl and hypocotyl make up the embryo.

Apply the iodine test to some of the crushed cotyledon in a watchglass. Do the same to the embryo. It will be found that starch is stored in the cotyledon, and not in the embryo. Contrast this with the condition in the corn seed and the diagram.

A-64. Germination [10, 9, 8]

It is relatively easy to demonstrate that seeds need access to air in order to germinate. Somewhat more sophisticated techniques are required to show that oxygen is the portion of air that is required.

(a) Seeds Need Air for Germination. Half-fill two wide-mouth bottles with cotton or sawdust and saturate with water. Cover the cotton or sawdust with a layer of bean or pea seeds that have been soaked overnight in water. Insert a stopper in one; leave the other open. Add just enough water to the latter to replace evaporation losses.

In a matter of a few days this experiment should provide evidence that air is necessary for seed germination.

(b) Seeds Need Oxygen for Germination. Prepare two wide-mouth bottles of seeds for germination as described in (a).

Put 5 gm of dry pyrogallic acid in the bottom of a liter mason jar. Place one of the bottles of seeds in the jar. Pour 50 cc of 1 percent sodium hydroxide over the pyrogallic acid and immediately screw the cap of the mason jar down tightly. The reaction of the sodium hydroxide and the pyrogallic acid removes all oxygen from the air in the jar.

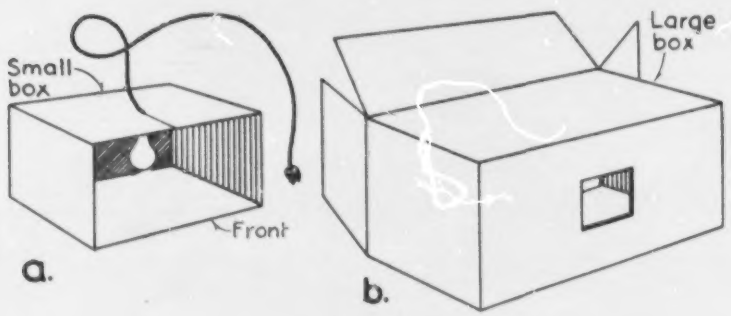
Place both groups of seeds together at room temperature so that all germination conditions are the same except for the absence of oxygen in the bottle in the liter jar. In several days, the need for oxygen for seed germination should be evident.

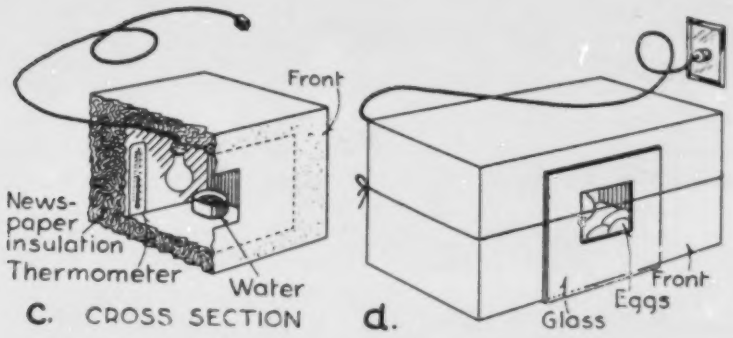
A-65. Incubation of Fertilized Chicken Eggs [8, 11, 6]

Incubate some eggs and break some open at intervals to observe the development of the chick embryo.

A very satisfactory incubator that can be made at little or no cost is shown in the diagrams. A little experimentation is necessary to get the incubator to maintain a constant temperature of about 39.4° C, which is the right temperature for hatching hens' eggs. This can be accomplished by trying bulbs of different wattage and by adding or removing some of the paper used for insulation.

After the incubator is maintaining the correct temperature for the incubation of hen eggs, 39.4° C, put a few fertile eggs in the inner box. After three days break one of the eggs into a shallow white dish; an old china saucer or sauce dish is satisfactory. The embryo will be, or should be, at the top of the egg, so great care should be taken in cracking the shell and pouring the contents out into the dish so that the embryo is still uppermost. A three-day embryo shows the heart already beating. It will remain beating for about 30 or more minutes, so that all pupils can observe it. If it slows down, add a little saline solution.



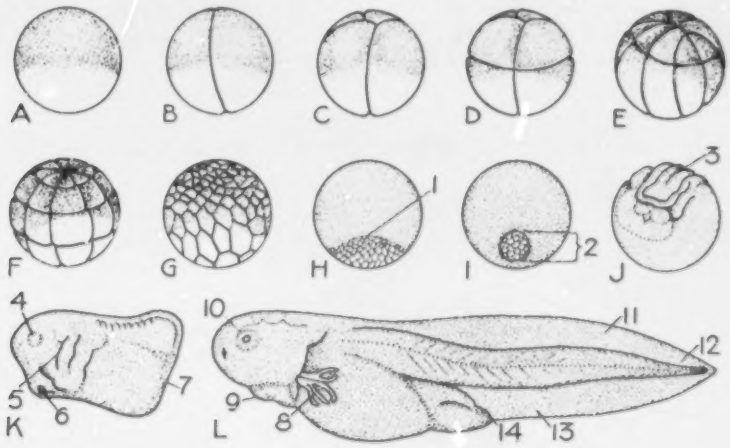


A four-day embryo will show heartbeat and the beginnings of embryonic membranes.

If desired, some eggs can be left in the incubator for the full 21 days to see if a chick will hatch. If it does, leave it in the incubator for a few hours until it dries off. Then remove it to a warm place and supply chick feed and water.

A-66. Embryology of the Frog [14, 13, 12]

Masses of frog eggs can be collected from ponds in the spring. Those that have been fertilized will be found with the black side of the egg up. Those with the white side up are either dead or have not been fertilized.



Divide the eggs into clumps of about 50 eggs each, discarding, where possible, dead or unfertilized eggs. Put each clump into a large-mouth jar about three-quarters full of pond or aquarium water with a few water plants. This will provide the water and surface area necessary to supply the needed amounts of oxygen, and the plants will remove waste carbon dioxide. Each day remove an egg and examine under a tripod magnifier.

Pupils can individually maintain developing eggs in test tubes. Place a single live fertilized egg in a test tube about two-thirds full of pond or aquarium water. Each day, have pupils cork the tube, turn it on its side and examine the developing egg under a tripod magnifier or dissecting microscope. Drawings can be made daily to keep a record of the developing embryo. See the diagram as a guide. After examination, the tubes should be unstoppered and placed in racks until the next day's examination.

After hatching, the tadpoles may be fed bits of boiled lettuce leaf. Feed in the morning, and remove any uneaten food at the end of the day so that the tadpoles are not killed by the decay products of the uneaten food.

Frog Development

Stages:

A. Single cell
B. Two cells
C. Four cells
D. Eight cells
E. Sixteen cells
F. Thirty-two cells
G. Many cells
H. Beginning blastopore
I. Yolk plug
J. Neural folds
K. Early embryo
L. Tadpole

Labels:

1. Dorsal lip of blastopore
2. Blastopore
3. Neural groove
4. Eye
5. Gill clefts
6. Sucker
7. Anus
8. External gills
9. Sucker
10. Eye
11. Dorsal fin
12. Caudal fin
13. Vential fin
14. Anus

A-67. The Life Cycle of a Flowering Plant [22, 19, 2]

Plant some bean, pea, or radish seeds in a flower pot of rich soil.

Make daily observations of the changes that take place in the appearance of the plants as they grow. If possible, keep the plants growing until they produce flowers and seeds. Records should be kept by means of drawings of all significant changes in the appearance of the plants during the life cycle.

A-68. Life Cycle of the Fruit Fly [1]

Several generations of fruit flies may be raised with a minimum of attention. Prepare a suitable habitat by dropping a piece of ripe banana or a few grapes into a 250 milliliter beaker. Fit a paper funnel into the top of the bottle. Soon fruit flies will go to the fruit at the bottom of the bottle but will find it difficult to escape because of the paper funnel. In a short time flies will deposit eggs on the fruit.

When six or more flies have entered the bottle, remove the paper funnel and plug the top with absorbent cotton. With this number of flies there should be some males and some females. Females can be distinguished from the males by their larger size. The female has a slightly broader abdomen than the male with small lines across the tip. The smaller male has a black-tipped abdomen.

Larvae will emerge from the eggs in a couple of days and feed on the fruit for about a week and then pupate. A piece of crumpled paper toweling can be dropped into the bottle for the larvae to crawl on and pupate. After five days some of them will change to adults. The flies will mate a short time after emergence. (See diagram in A-28 on p.52)

A new bottle or habitat can be prepared and a third generation established. In this way the entire life cycle can be observed in a very short time.

A-69. School Ground Plant Census [14, 13, 12]

Prepare plant census lists of habitats found on or near the school grounds. Classify each habitat as either aquatic or terrestrial. Such areas might include:

- A clump of trees
- A dense wooded area
- A base planting of shrubs
- A portion of the lawn that is mowed regularly
- The edge of a well-trodden gravel walk
- A steep slope in a field
- The edge of a stream
- Cracks in the sidewalk

Many other habitats will suggest themselves after a survey of the particular school location. Each has its own combination of plant species, as a plant census will indicate. This is an excellent activity for small groups.

A-70. Studying Aquatic Communities [1, 2, 4]

(a) In many schools it is not practicable to take long field trips. Ponds and streams are frequently some distance from the school. Where and when it is possible, however, at least one trip to a pond or stream should be planned and taken. In cities it is usually possible to arrange for a trip to a park that has a pond or stream. This one trip might be devoted mostly to collecting but could incorporate several of the other activities suggested in this section.

For collecting from ponds or sluggish streams filled with water plants, the common household wire-mesh strainer with a handle makes an inexpensive net. To collect, have the pupils scoop with the strainer along the surface of the edge of the pond or stream. In deeper water draw the net along the bottom of the pond or stream, particularly among the plants. For collecting farther out in the water without wading, the strainer handle can be fastened to a broom handle to give it added length.

For collecting from rapid streams, fasten a piece of wire screening between two round sticks such as broom handles. Set this upright against the stream bottom and stir up the stones just upstream. Plants and animals are dislodged and carried down into the net by the current.

(b) When pupils arrive at the pond or stream, even before they start to collect, ask them to stand still and identify as many plants and animals as they can. At most ponds there will be cattails, pond lilies, pickerel weed, dragonflies, damsel flies, water striders, frogs, tadpoles, and even some birds.

(c) The materials collected in the nets may be examined right in the net or may be turned out into a dish for more careful examination. If sufficient water is not scooped into the net, add some to the dish to float the plants and animals.

White enamel pans make excellent study pans, but any white dish may be used. The small plants and animals will stand out well against the white background. Use a hand lens or magnifying glass to see some of the smaller forms more clearly. Try to identify some of the small animals and insects by referring to pictures in a book on pond life.

If not much of interest is scooped up in the net, pull up some of the water plants from the mud at the edge of the pond. Float them in the white pan and look for water insects. Leeches, worms, and shed skins of dragonflies and damsel flies may also be found.

A-71. Miniature Communities [21, 19, 2]

(a) Establish a small aquarium with a few water plants, especially some eel-grass. Obtain a few aquarium snails from a pet store or a biological supply house. The common disc pond snail found among the plants of a muddy-bottomed pond may also be used.

Some snails are egg layers and some are live bearers. If possible get egg-laying snails. In a short time after the snails have been introduced to the aquarium they will lay eggs in jelly-like masses. The eggs may be readily seen within the mass, some may be laid on the sides of the aquarium. The development of the eggs may be watched through the glass with a hand lens. The eggs hatch in two to three weeks, depending largely upon temperature. Stages of development are gradual.

Some of the snail eggs may be transferred to a snail dish supplied with a little water and plant material from the aquarium. Observe the development of the eggs with a hand lens and keep a record of the day-by-day progress.

Observe the adult snails and notice how they move and eat. Notice that when they are touched, they withdraw into their shells and fall to the bottom of the aquarium.

(b) A habitat terrarium group may be set up in an empty aquarium. Gather representative plants and soil from a single plant community.

Before collecting the plants, place about 3 centimeters of gravel on the bottom of the aquarium and cover this with a layer of charcoal. Cover the charcoal with 3 centimeters or more of soil from the habitat.

In transferring the materials to the terrarium, keep as much soil attached to the plants as possible. Handle the plants gently to avoid breaking small roots and to avoid disturbing the position of seeds that may be in the soil and not yet germinated.

Arrange the materials as nearly as possible as they were growing in their natural habitat. After planting, sprinkle well with water but do not saturate the soil. In the spring, a cover for the terrarium is ordinarily not necessary unless the plants came from a moist woods.

Duplicate moisture and light conditions of the plant community as closely as possible. Terrariums representing communities under trees and shrubs should be shaded from direct sunlight. This may be done with a piece of cardboard or by painting the side of the terrarium facing the windows with green poster paint. If the habitat from which the plants came is near the school, it will be possible to check the moisture conditions of the soil frequently and water the terrarium accordingly.

If several aquariums are available, it will be interesting to set up several habitat group terrariums representing the plant communities found growing in different environmental conditions. Each habitat terrarium should be provided with a card bearing the type and location of the habitat as well as a list of the principal plant species included in the terrarium.

A-72. Succession [23, 20, 18]

(a) Locate places on the school grounds where seedlings have developed under natural conditions. Then plan a short fieldtrip to observe them. Seedlings of maples and other trees are usually very numerous in spring, even in cities. Discuss the reasons why few such seedlings ever develop into trees. Point out that the overabundance of seeds is of value in conserving the soil by insuring plentiful seed dispersal in areas where plant life has been destroyed. The numerous seedlings compete with each other for moisture, light, and living space but not many can survive. The activities of man and plant-eating animals further reduce their numbers.

A fieldtrip of this kind presents an opportunity to introduce the concept of plant succession in an elementary way. Ask pupils what would happen if the area surrounding the school were left entirely undisturbed by man for several hundred years. The answer is, of course, that different kinds of plants would move in and compete with each other. For a while, these would be mostly weeds and other low-growing plants. Gradually trees would crowd

out the low-growing plants and shut off their light. Finally a climax forest like the one the early settlers found would result.

Find out what kind of climax forest existed in your area before the first settlers came.

(b) Find and observe actual examples of plant succession on or near the school grounds. A vacant lot, backyard, or portion of the school campus that is not regularly mowed will usually provide suitable examples.

During the first year that land is uncultivated, there will usually be a fine crop of weeds. Many of the weeds will be annuals, or plants that produce seeds the first season and then die. Gradually biennials (plants that live two years) and perennials (plants that live more than two years) crowd out the annuals. As time goes on, woody plants crowd out the herbaceous plants. Finally, trees form an overhead canopy and the cycle of plant succession is complete.

The observation of stages in the sequence of plant succession makes an excellent objective for a fieldtrip. On such a trip, the leader might call particular attention to the usefulness of weeds in protecting and building soil, to the fierce competition for light, moisture and living space on the part of plants and to the kinds of plants that seem to be most numerous or conspicuous at various stages of the cycle of succession.

Point out the biological relationship that exists between weeds and weed-eating birds. Weed seeds provide food for birds and birds aid in seed dispersal.

(c) Prepare three hay infusions using similar jars and equal amounts of dried grass and water from the same sources. Place one in a sunny place, one in a well-lighted shady place, and one in the dark. Compare the microscopic life found in the three infusions at convenient intervals after the first week.

A-73. Stored Sunlight [17, 14, 13]

(a) Light a match and watch it burn. Raise the question of where the heat energy really comes from.

Trace this energy back to the sun. If the match is wooden it came from a tree whose leaves manufactured food from water and air with the aid of sunlight. If it is a paper match, the paper was made from wood whose energy came from the same source.

(b) Make a list of common fuels. Coal, petroleum, and other fossil fuels are believed to be the remains of green plants or of animals that ate green plants. It will be interesting to trace the energy of particular refined fuels such as gasoline back to the sun.

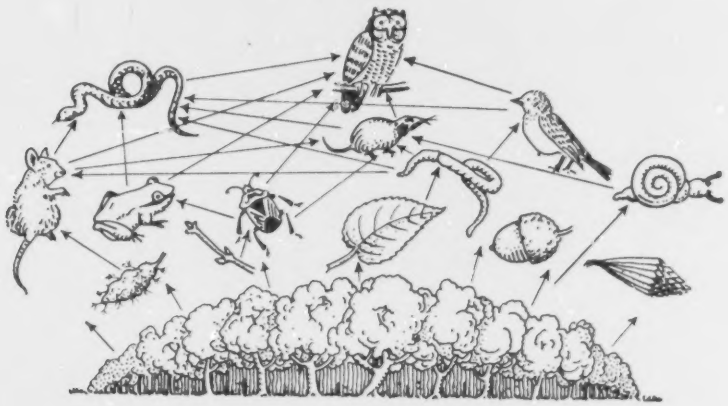
A-74. The Construction of a Food Web [23, 19, 13]

Find out about the food of animals observed in a particular habitat and construct a diagram of the food web of that habitat. In the rather simple example given, the arrows point away from the organism being eaten. (See the diagram.)

The diagram may contain only information actually observed or may include information obtained from reference books as well. Whichever is the case, it should be clearly indicated on the diagram. If both direct observations and material from reference books are included on the same diagram, they can be distinguished by the use of different colored lines for each type of information.

Such a diagram makes an excellent long-term class project. It may be started on a large piece of poster board mounted on the bulletin board and added to during the rest of the school year as additional information is discovered by various members of the class.

Similar diagrams may be constructed to indicate the food webs in surrounding habitats. It will soon be apparent that certain animals will cross from one food web to another, producing feeding interrelationships among several habitat communities. For instance, the garter snake from the shrub community may eat frogs from the streamside community; the wood thrush living in the woods will feed on insects in the shrubs, and the owl from the woods community may eat the rabbit. (See the diagram.)



This technique emphasizes the fact that simple food chains intertwine and cross one another to produce a complex web that includes all organisms in the habitat. It becomes apparent that adding or eliminating a single species from the community affects many other species in the web and may upset it entirely. Then a new web develops.

A-75. The Effects of Light on Plants [23, 22, 21]

Select two flower pots that contain young seedlings of similar size. Wrap a desk blotter or piece of black poster board around one of the pots and fasten it with rubber bands or cord to form a cylinder which shuts out the light.

Remove the cylinder every few days and compare the two pots of seedling.

A-76. Consumer Organisms [17, 14, 1]

(a) Examine living grasshoppers and other insects with a hand lens as a classroom laboratory exercise. Insects can be "put to sleep" by placing them in a jar of carbon dioxide for several minutes.

Place marble chips and dilute acid in a gas generator. Connect the delivery tube to a gas bottle containing one or more insects as shown. When the insects become quiet, they may be removed from the bottle and examined. Look closely at the mouth parts, antennae, eyes, legs, wings, and abdomen.

The insects will usually recover from the effects of the carbon dioxide within a few minutes.

(b) Visit a place where goldenrod is growing and look for stalks that have round enlargements or galls on the stems. Collect a number of these galls and bring them to the classroom for study.

Cut the galls open with a knife. If they are not too old, each will contain the larva of a gall insect. Some may be empty but show a tiny hole where the insect has escaped.

More interesting galls can often be found on oaks and various other plants.

Develop the meaning of the terms "parasite" and "host" and cite a number of examples. Point out that parasites are often useful in limiting the numbers of some living things that are harmful to man.

(c) Find a dead tree or rotting log. Peel away some of the bark and observe the work of bark beetles and other small animals. Look for fungi growing on the rotting wood and in the vicinity. Roll the log over and look for animals beneath it. Rodent burrows are found under many such logs.

A-77. Mushrooms [6, 1, 7]

Mushrooms can frequently be found, even on the shortest fieldtrips. It will be interesting to collect a few specimens and to use them to make spore prints.

Over a thin piece of cardboard spread a thin coat of mucilage-water mixture or egg white. Remove the stem part of a fully opened mushroom and push three toothpicks into the side of the cap. Rest the ends of the toothpicks on small blocks so that the cap is suspended a short distance above the cardboard. Cover with an overturned glass dish and leave undisturbed for at least 24 hours.

Millions of spores will fall on the sticky surface which is kept moist by the damp air under the dish. When the dish and cap are removed the surface will dry and leave a permanent print. For mushrooms that have light-colored spores, dark paper should be used.

The observation of mushrooms and the making of spore prints present an opportunity to point out the part that fungi play in the economy of nature. Fungi such as mushrooms make no food of their own. They live on dead or decaying matter and help enrich the soil. Each of the millions of spores can start a new plant if it finds a suitable place to grow.

A-78. Equilibrium in Communities [22, 21, 17]

(a) Count or estimate the number of eggs in a frog egg mass. From this count it is obvious that a female produces many more eggs than ever mature into frogs, otherwise the earth would be covered with them. Ask pupils to make a list of all the animals, including humans, that feed on tadpoles and frogs.

(b) With a spade, carefully cut out a block of soil including its plants from under a shrub. Cut a similar block of the same size from a sunny grassy area. Blocks should be from 20 to 30 centimeters square and should be removed with as little disturbance of soil and roots as possible.

Interchange the two blocks, placing them in the ground flush with the surrounding soil. Water well as soon as they have been moved, but not after that. Make frequent observations over a period of several weeks to determine what kinds can survive in their new environment and which ones are not able to adapt to the changed conditions.

Interchange transplants can be made between other pairs of contrasting environments. Much information can be gained concerning the adaptability of various plant species by this technique.

(c) If possible, visit a fish hatchery. If an actual fieldtrip to a fish hatchery is not possible, show a film illustrating the work of a fish hatchery. Point out some of the reasons why fish hatcheries have been established. Humans have overfished some of the species; our demand is greater than the natural supply; and we have destroyed some of the factors of the natural habitat of the fish so that they can not reproduce or survive. Humans have also removed some of the natural covering of the earth, cut trees and allowed soil to erode. Many streams are now too muddy, too warm, or have great fluctuations in their water level, so that they are no longer suitable habitats for fish.

A-79. Rate of Humus Formation [17, 13, 19]

The rate of decomposition of organic matter to form humus can be determined by placing pieces of filter paper in the soil. Filter paper, like dead vegetation, is largely cellulose.

Insert a spade or garden trowel about 15 centimeters into the ground vertically and open a slit by pushing the handle of the tool 5 centimeters forward. Remove the tool from the ground and insert a piece of filter paper folded once so that about 2-3 centimeters remains above the surface of the ground. Tramp the ground firm about the filter paper with the foot.

Remove the filter paper from the ground at the end of two or three weeks, being careful not to tear it. This is best done by lifting out the soil containing the paper with a shovel or trowel and carefully separating it from the soil. Examine the paper for evidences of decomposition.

The appearance of the paper will depend on the activity of soil micro-organisms. There undoubtedly will be colonies of various molds and bacteria present. In moist woods, portions of the paper may be completely decomposed.

Filter papers should be inserted in the ground in a number of locations around the school grounds under a variety of conditions of vegetational cover.

A-80. Soil Formation [17, 14, 8]

(a) Place one of the larger flat pieces of rock from the classroom collection on a piece of newspaper and rub a smaller rock over it. Continue rubbing until some rock is worn from the rocks. Examine the dust and compare it with samples of soil.

The activities of animals, the action of freezing and thawing, the force of gravity, the work of streams and many other factors are continually rubbing rocks together and wearing them away. With the aid of plants, the dust that is worn from the rocks may eventually become good soil.

Call attention to the long period of time needed to form good soil and the need for conserving it. Grass fires, forest fires, and wasteful farming practices remove the cover of vegetation from the soil. Discuss various means of preventing erosion and conserving the soil.

(b) Place some small freshly broken pieces of rock in a jar half-filled with clear water. Close the lid of the jar and have several pupils each shake the jar 100 times. Note the appearance of the water after the jar has been shaken at least 1,000 times.

Remove the rocks and allow the sediment to settle to the bottom or filter it out through a paper towel or filter paper.

Compare the rocks that have been shaken in water with freshly broken pieces. Note that the sharp edges have been rounded and worn away.

(c) Find rocks or rock ledges where mosses and lichens are growing. Scrape some of the plants off and notice that bits of rock flake off, loosened by the chemical action of the plants.

A-81. Soil Composition [1, 2, 4]

Examine freshly broken rocks with a hand lens and look for crystals of minerals in the rock. Crystals of different minerals will differ in size, shape, and color.

Examine a small quantity of sand under a low-power microscope or with a good hand lens. The almost colorless crystals are those of the mineral quartz, the commonest mineral on earth. Crystals of other minerals can also usually be found in sand. Look for them and then identify them.

A-82. Making a Soil Profile [17, 14, 1]

(a) With a spade make a vertical cut to a depth of about one meter into a sloping area, such as a steep roadbank or hillside. Several distinct layers or horizons of soil will be noticed. These layers develop under the influence of climate and living organisms.

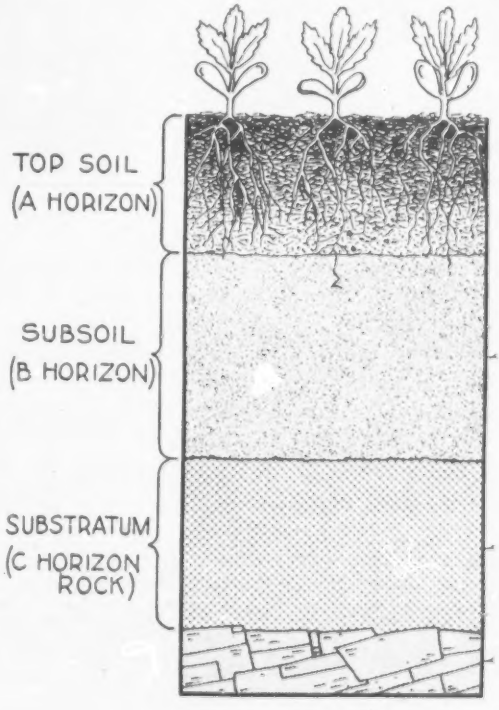
The top layer will be rather dark colored and contain organic material mixed with mineral matter. This is the topsoil. Soil scientists call it the "A layer."

Under the topsoil is the subsoil or "B layer." The subsoil is usually a lighter, richer brown color than the topsoil. Many soluble minerals and much of the fine silt from the topsoil is carried down to the subsoil by water seeping down through the soil. The subsoil, therefore, tends to be composed of finer material and to be more closely packed than the topsoil.

The "C layer" may not be reached in your cut. It is the unweathered parent rock material and may be many meters beneath the surface.

Compare the texture and compactness of the topsoil with the subsoil. Notice that root growth is much more abundant in the topsoil than in the subsoil.

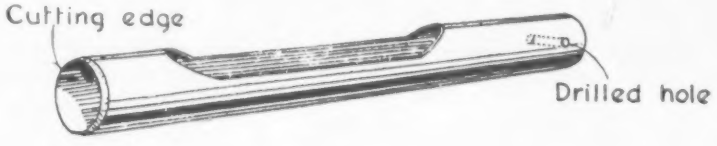
See the diagram for a schematic view of soil profile.



(b) A soil tube for the collection of soil samples from various depths for analysis can easily be made from a length of automobile tailpipe. Cut the pipe to a length of about 30 centimeters. By hammering, roll one end in slightly and sharpen it with a file or grinding wheel. Drill holes on opposite sides near the other end so that a steel rod can be inserted as a handle.

With a hacksaw cut out a section of the pipe as shown in the diagram so that the soil in the tube is visible.

To obtain a soil sample with the soil tube, remove the surface vegetation from an area of the diameter of the soil tube. Place the sharpened end on the ground and press downward with a twisting motion. Soil samples up to 15 centimeters in thickness can be obtained with little effort. Remove the soil from the tube to a container. Using the same hole, additional samples can be obtained to a depth of 30 centimeters.



(c) With the soil tube described above in (b), remove soil cores from several areas around the school campus. Choose different habitat areas, such as shrubbery, a grassy area, an area free from vegetation of any sort, and the top of a slope. Other possibilities will suggest themselves in various local situations.

The cores may be preserved for a time by wrapping them in cellophane and sealing with sticky tape. Display each soil core on a separate piece of paper. Indicate on the paper the part of the core that represents topsoil, and the part that represents subsoil. Label the displays with the location from which the soil came, and the type of vegetation growing there. Try to discover what relation exists between the type of vegetation and the amount and character of topsoil present.

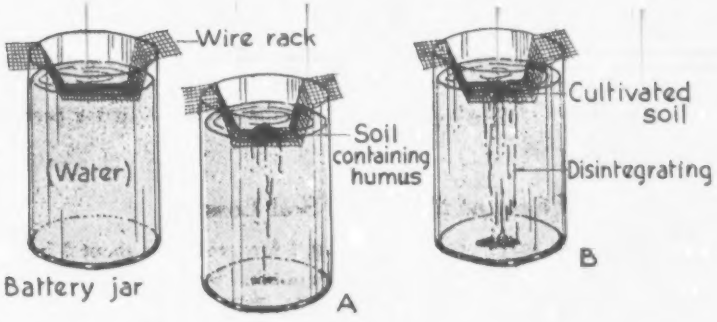
A-83. The Effect of Humus on Soil Structure [8, 10, 14]

The role of organic matter (humus) in soil structure cannot be over-emphasized.

Take two battery jars and to each fit a wire rack made from heavy gauge hardware screen as in the diagram on the next page.

Collect, two lumps of soil just under the sod from (A) a natural sod fence row or from a woodlot containing old trees and (B) a cultivated field that has been farmed heavily. The lumps should be about the size of an egg.

Fill the battery jars with water leaving room for displacement. Place the lumps of soil in the racks and lower them into the water. Have the pupils watch closely and record the results.



The soil from the cultivated field will tend to crumble and fall to the bottom of the jar. The other will be almost unaffected by the water, since its large amount of humus preserves the soil structure in spite of soaking. Point out that soil deficient in humus becomes muddy when wet, thereby losing its porosity for water and air vitally needed by plants. Water falling on such soil runs off instead of soaking in and erosion results.

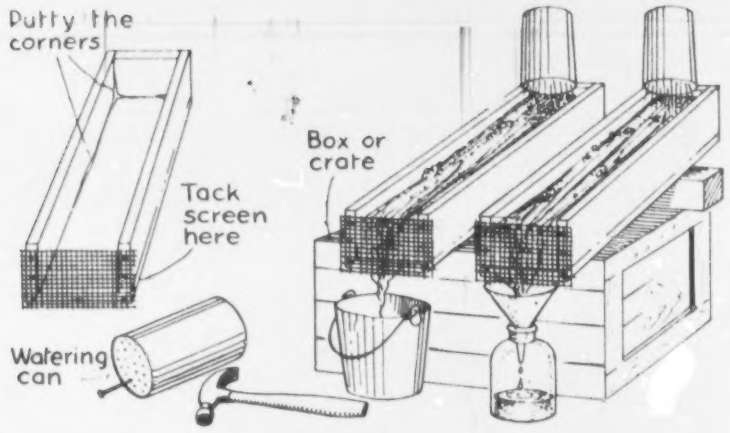
A-84. Erosion [20, 18, 1]

(a) A pair of wooden troughs or trays similar to those shown in the diagram represent a very effective device for conducting various soil conservation and erosion experiments. Such troughs can be made quickly in the woodshop or even in the classroom. For best results they should be not less than 60 centimeters in length and 15 centimeters in width, closed at one end. A little putty around the inside corners will make them water-tight.

Pieces of wire mesh or screen should be tacked over the open ends of the troughs as shown. Large funnels and glass jugs or ordinary pails can be used to catch the overflow water.

(b) On practically every school campus, a suitable place can be found for carrying out conservation experiments and demonstrations outdoors. The following experiments can, however, be conducted indoors as well as outdoors, using the pair of trays described in (a).

- Fill one tray with loose soil and the other with firmly packed soil. With both trays tilted slightly, water each equally with a garden sprinkler or large tin can with holes punched in the bottom. Observe which soil is moved away faster and the nature of the run-off water.



- Fill both trays with soil but cover one with sod. Water equally and observe as before.

- Fill both trays with soil but give one more slope than the other.

Possibilities for many additional experiments are obvious and are often suggested by pupils.

(c) On a windy day observe what the wind does to leaves, twigs, and other debris on the ground. Look in corners protected from the wind and notice that soil, leaves, and other materials are sometimes deposited there.

A-85. Contour Plowing [11, 9, 8]

Construct two boxes about 60 centimeters long, 30 centimeters wide, and about 8 centimeters deep. Fill both boxes with soil taken from the same place. Elevate the boxes and place a beaker under each notch in the end of the boxes. Using a pencil, make furrows across the soil in one box and up and down in the other. Fill two sprinklers with water and sprinkle each box evenly and slowly.

Make a comparison of the rate of flow into the two beakers and notice the difference in their contents. From this, pupils can see that contour farming is one of the simplest soil conservation practices.

A-86. Nitrogen-fixing Bacteria [1, 14]

Dig up a clover plant with a spade or shovel, being careful to disturb the roots as little as possible. Dip the roots into a pail of water to wash off the soil. Look for the little nodules of nitrogen-fixing bacteria attached to the roots. Discuss the mutually beneficial relationship that exists between the clover and the bacteria, pointing out what each gives to and receives from the other. Point out the advantage of including legumes in crop rotation.

A-87. Rate of Evaporation from Soil [17, 13, 12]

The rate of evaporation is very important to plant growth, and is determined by a number of factors, including relative humidity, temperature, wind, and amount of sunshine.

Obtain a number of tin cans of the same size. Cans that condensed soup comes in are very convenient for this purpose. Place such cans, filled to the brim with water, in a number of plant environments, such as in the sun on the lawn, in the shade at the base of a tree, on the ground under a planting of shurbbery, in a wooded area, and on a bare area. At the end of 24 hours, carefully measure the distance from the rim of the can to the level of the water and record the depth of water that has evaporated. Determine the areas in which evaporation has been the greatest and those in which there has been the least amount of evaporation. Try to decide what factors in the environment have been responsible for the amount of evaporation observed, and if there is any relation between the amount of vegetation and the amount of evaporation.

A-88. Water [17, 14, 1]

(a) To find out if moisture is needed for seed germination, prepare two seed testers in exactly the same way. Keep one moist but do not wet the other.

(b) Observe the water level of a pond, lake, or stream and notice any evidences that the water level has receded. Relate this to the season of the year and the influence of man's activities in the area under observation.

(c) Ask pupils to cite places in the vicinity of the school where there is evidence that the water table is near the surface. Swampy or marshy locations, even though they are small in area, can usually be found at a distance that is not too far for a short fieldtrip.

In conducting a fieldtrip of this kind, one of the significant observations that can be made is the difference in the vegetation as compared to adjacent, drier areas. Some of the plants such as cattails, marsh marigolds, pussy willows and various swamp grasses, which grow only in wet locations, can be identified by their common names. If the fieldtrip is taken in early spring, it will often be possible to find the water table by digging a small hole with a shovel. Attention should be called to the fact that the water table is usually nearer the surface in spring than at other times of the year.

A-89. Water Conservation [17, 13, 12]

(a) Plan a fieldtrip to a sewage disposal plant, if one is located nearby. Learn how much raw sewage can be treated by the plant, what steps are involved, the effectiveness of the treatment and what is done with the final products.

Discuss the relation of proper sewage disposal to water pollution. Call attention to the fact that much untreated sewage is still drained into lakes and streams.

(b) Weigh a large handful of dry duff (See 91 [b]). Add as much water as the duff can absorb and weigh again. Squeeze out as much water as possible into a vessel and weigh this. Relate the results to the importance of forests in the prevention of floods and soil erosion.

A-90. The Economic Importance of Forests [7, 5, 8]

Estimate the number of board feet of lumber that can be obtained from logs that might be cut from trees near the school.

First determine the point on the tree where the upper end of the log should be sawed. Using a long pole, find the distance between this and the lower cut.

Next find the circumference of the tree in inches by putting a string around it and measuring the length of the string. Square this number and multiply the result by 0.003. Multiplying the result by the length of the log in feet will give the approximate number of board feet of lumber that can be obtained from the log.

After the amount of lumber has been estimated, pupils will be interested in finding its value. Several trees may be used for this activity, with pupils working in groups.

A-91. Forest Destruction [17, 14, 8]

(a) Ask pupils to look in the vicinity of the school for young trees that have been girdled or damaged by mice or rabbits. Severe damage to young fruit trees or ornamentals is common even in cities. Similar damage occurs in many plantings of seedlings as well as in established forests. If such damage is found, a visit to the location might be included in one of the fieldtrips.

(b) Collect some partly decayed vegetable matter, technically called duff, from the surface of a wooded area. Place it in a tray and pulverize it completely by rubbing it between the hands. Dry it very thoroughly by heating it over a burner several times on successive days. Then press a lighted cigarette into the surface of the dry duff and direct a gentle stream of air upon it by means of an air pump. This should demonstrate convincingly that carelessly dropped cigarettes can really start forest fires when conditions are favorable for combustion.

A-92. The Role of Fire Lanes in Forest Planning [8, 9, 10]

The importance of fire lanes in forest planning as a means of controlling forest fires can be easily demonstrated.

Make-believe forests are made up in 30 by 35 centimeter metal pans with sand on the bottom of the pan. Filter paper trees are placed in the sand. To construct these trees, cut sheets of filter paper into four parts and roll each part to form a cone. Paste each piece so that it retains it shape. The cone will represent the foliage of the tree and the trunk will be represented by wooden matches(with the heads facing up). Place the e

trees in an unplanned forest area. Start a fire in this area and note the progress of the blaze. The entire area will become a mass of burned over trunks.

Now set up the second simulated forest with carefully planned fire lanes. Start a fire here and note its progress. It will be noticed that the fire stops at the fire lanes and it can be easily extinguished by fire fighting "equipment" consisting of a medicine dropper.

A good addition to this is to use a small electric fan to create a breeze in the forest, for forest fires do create very strong drafts which make them burn more actively.

A-93. Reforestation [6, 1, 8]

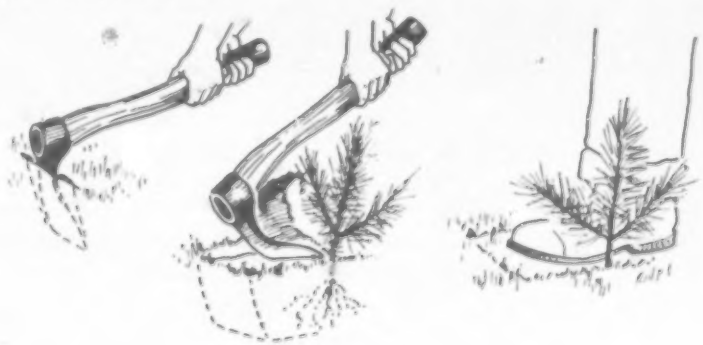
Arrange a demonstration of reforestation by the planting of seedlings. If possible, real seedlings should be obtained and planted in a suitable place on the school campus. If no suitable place is available, short evergreen twigs may be used to demonstrate this method of reforestation.

The "slit method" is the commonest and the most practicable for the average site. A heavy stroke is made with a grub hoe. The handle of the hoe is then pulled back so that a slit is opened in the ground. The seedling is set about 1 centimeter deeper than it grew in the nursery. After it is in place, the grub hoe is withdrawn and the earth is packed around the roots by pressing hard with the foot. Planting is done most efficiently if two persons work together, one making the slit and the other setting the seedling.

In light soils, a better job can be done by digging a small hole with a grub hoe or shovel, setting the tree in the hole and pulling the soil around the roots by hand. This method is slow and impracticable where there are many trees to plant.

In heavy sod, a third method is sometimes necessary. A small circle is cut in the sod with a shovel and the piece of sod within the circle is turned upside down. The seedling is then planted in the center of the inverted piece of sod. This method eliminates competition by the surrounding grass until the seedlings are established.

For most evergreens a spacing of from 2 to 3 meters apart each way has proved to be most successful.

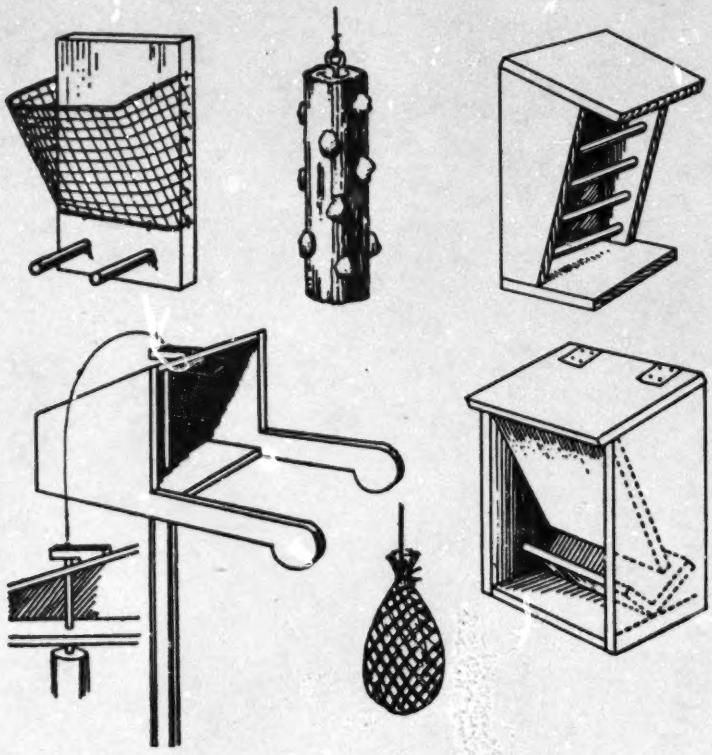


A-94. Observing Wildlife [14, 2, 1]

(a) Select an appropriate place for a bird-feeding shelf or suet feeder that can be seen from the classroom window. Choose one of the feeders shown in the diagrams and construct it as a classroom project. Observe the kinds of birds that come to visit the feeder.

The aggressive manners of some of our least welcome birds, such as starlings and English sparrows, often drive the more desirable birds away. Furthermore, the feeding sometimes seems to make such birds as chickadees, nuthatches and woodpeckers lazy so that they spend less effort looking for insects. Try to decide, on the basis of observation, whether feeding actually helps the birds.

Feeding really helps during an ice storm. Many birds starve to death if their food is covered with ice for even a day or two.



(b) State parks, State and National forests and wildlife refuges help in the conservation of animals and bring about a better understanding of wildlife problems. They also encourage hunting with a camera and binoculars instead of with firearms. Compare the relative values of each method of hunting.

If possible, pupils should have the experience of taking a well-planned nature walk with a competent naturalist. Even one such trip opens up an entirely new world.